

## DOCTOR OF PHILOSOPHY

### Development of a quality assurance model for poultry meat production

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# Development of a Quality Assurance Model for Poultry Meat Production.

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*A thesis submitted in partial fulfilment of the University's  
requirements for the Degree of Doctor of Philosophy*

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Coventry University

(Royal Agricultural College, Cirencester)

## **ABSTRACT**

The study has defined the position with regard to existing and evolving United Kingdom (UK) and European Union (EU) legislation, world trade agreements and institutions, global trade in chicken meat and market Quality Assurance (QA) standards in a series of peer-reviewed published papers and working papers. The development of global food supply chains can be a key driver in the harmonisation of international legislation, product and private assurance standards. Indeed compliance with legislation and retailer requirements has been a key market driver in the development of private assurance standards.

The key objectives of the research were to examine current assurance schemes within the integrated poultry meat supply chain and the influence of regulation and external market drivers within the integrated poultry meat supply chain; develop and test a QA model for the poultry meat supply chain with a view to both baseline and higher level standards including the development of a business benchmarking system utilising a pre-requisite programme (PRP) and key performance indicators (KPI); and to assess the ability of the QA model to deliver regulatory and policy compliance whilst meeting varied business and market needs for an internationally traded product.

This study has shown that a QA model is capable of providing a framework within which the poultry meat supply chain can operate. The legislative and performance requirements have been translated into quantifiable performance indicators which can be used to measure supply chain performance. This can assist differentiation of products at the point of consumption and give a quantifiable measure of the extrinsic value that has been added. This approach will therefore aid the communication of the benefits of differing methods of poultry meat production and afford the consumer the opportunity to make a more informed choice when purchasing meat products.

## **DECLARATION**

The work within this thesis is based on the author's independent study at the Royal Agricultural College, Cirencester under the supervision of Dr R. Baines, Dr S. Chadd and Professor D. Leaver. The author is responsible for the experimental work, the interpretation of the results and the conclusions discussed within this thesis. All assistance and advice received from colleagues has been acknowledged. The concepts and ideas expressed in this thesis, which are not referenced to others, are those of the author and not of the Royal Agricultural College or Coventry University.

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Louise Manning

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## **GLOSSARY OF TERMS**

ACP	Assured Chicken Production
AFTA	Asian Free Trade Agreement
AGP	Antibacterial Growth Promoters
AI	Avian Influenza
AoA	Agreement on Agriculture
ASEAN	Association of South-East Asian Nations
BIS	Bank for International Settlements
BPE	Birdplace Efficiency
BREF	BAT Reference
BSE	Bovine Spongiform Encephalopathy
CAC	Codex Alimentarius Commission
CAP	Common Agricultural Policy
CEO	Chief Executive Officer
CSR	Corporate Social Responsibility
CX	Cockerel
DEFRA	Department of Environment, Food and Rural Affairs
DOA	Dead on Arrival
DWI	Drinking Water Inspectorate
EC	European Community
EPEF	European Production Efficiency Factor
ETI	Ethical Trading Initiative
EU	European Union
FAO	Food & Agriculture Organisation
FAWC	Farm Animal Welfare Council
FCR	Food Conversion Rate (or Ratio)
FDI	Foreign Direct Investment
FLR	Feed Linear Regression
FMD	Foot and Mouth Disease

GAP	Good Agricultural Practice
GDP	Gross Domestic Profit
GCFG	Grampian Country Food Group Ltd
GMP	Good Manufacturing Practice
GS	Gait Score
HACCP	Hazard Analysis Critical Control Point
H5N1	Avian Influenza type
IBP	Iowa Beef Processors Inc.,
ILO	International Labour Organisation
INC	Incorporated
IPPC	Integrated Pollution Prevention and Control
ISO	International Organisation for Standardisation
JIT	Just in Time
KPI	Key Performance Indicators
MRP	Materials Resource Planning
NAFTA	North American Free Trade Agreement
ND	Newcastle Disease
NE	Necrotic Enteritis
NSP	Non-starch Polysaccharides
NVZ	Nitrate Vulnerable Zone(s)
OIE	World Organisation for Animal Health
PC	Policy Commission
POL	Point of Lay
PLC	Public Limited Company
PMI	Post Mortem Inspection
PRP	Prerequisite programme
PX	Pullet
RHM	Rank Hovis McDougall
RTA	Regional Trade Agreements
QA	Quality Assurance

SA	Social Accountability
SCAHAW	EU Scientific Committee for Animal Health and Welfare
SME	Small and Medium sized Enterprises
SPS	Sanitary and Phytosanitary measures
TBT	Technical Barriers to Trade (TBT) agreement
TD	Tibia Dyschondroplasia
TDS	Total Dissolved Solids
TNC	Transnational Corporations
TQM	Total Quality Management
TRIMS	Trade-related investment measures
UK	United Kingdom
UNECE	United Nations Economic Commission for Europe
US	United States
WHO	World Health Organisation
WLR	Water Linear Regression
WTO	World Trade Organisation
YOY	Year on Year



## SCIENTIFIC TERMS/INDICATORS

°C	degrees Celsius
CV	coefficient of variation
g	gramme
IQR	interquartile range
kg	kilogramme
kg/birdplace	kilogramme per nominal bird place
kg/m <sup>2</sup>	measure of stocking density – kilogramme of liveweight per metre squared
kg/m <sup>2</sup> /yr	measure of efficiency – kilogramme of liveweight per metre squared per year
kg/m <sup>2</sup> /wk	measure of efficiency – kilogramme of liveweight per metre squared per week
kWh	unit of energy – kilowatt (1000 watts) hour
L	litre
L/bird/cycle	litre per bird per cycle or litre/head
L/bird/day	litre per bird per day
L/m <sup>2</sup>	litres per metre squared
m <sup>2</sup>	metre squared
m <sup>3</sup>	metre cubed
mg	milligramme
p/bird	pence per bird
p/kg	pence per kilogramme
p/m <sup>2</sup> /wk	pence per metre floor space per week
ppm	parts per million
r	correlation coefficient
r <sup>2</sup>	coefficient of determination
SD	standard deviation
sem	standard error of the means
W	unit of energy - watt
Yr	year
%	percentage

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## CHAPTER 1 - INTRODUCTION

Poultry meat is a very popular, relatively cheap source of protein, with good nutritional value. There is a global market for a range of cuts and parts of the chicken i.e. white meat, dark meat, feet, wings and so forth. It can be quickly and easily cooked and can be purchased in a range of formats, which allows a varied means of preparation; and poultry meat is readily available in food service and fast food environments. Unlike other meats, there is no religious restriction on the eating of chicken meat other than slaughter method. Broiler poultry meat has little inherent flavour when compared with other meats such as lamb or beef, so chicken meat is very versatile and can readily take on the flavours from a range of other ingredients. This introduction begins with a brief description of the outline of the PhD thesis, research for which began in February 2002, on a part-time basis. The primary aim of the study is:

*To evaluate whether the mechanism of quality assurance is capable of consistently delivering compliance with regulatory and market requirements whilst still ensuring both individual business and supply chain viability.*

The key objectives of the study are:

- To examine the influence of regulation and external market drivers within the integrated poultry meat supply chain;
- To examine current assurance schemes within the integrated poultry meat supply chain;
- To develop and test a QA model for the poultry meat supply chain with a view to both baseline and higher level standards including the development of a business benchmarking system; and
- To assess the ability of the QA model to deliver regulatory and policy compliance whilst meeting varied business and market needs for an internationally traded product.

### 1.1 Quality Assurance

A literature review of previous work in the area of study identified that QA schemes are increasingly important in integrated food supply chains, from primary production to the consumer (Turner and Davies, 2002). Indeed, some researchers have put forward the proposal that QA

approaches are the future for agriculture especially as organizations "*move away from commodity markets and into the more profitable specialty products.*" (Sparling *et al.*, 2001). Early (1995) described QA as '*a strategic management function concerned with the establishment of policies, standards and systems for the maintenance of quality*', while as a result of benchmarking studies, Baines & Ryan (2002) considered that QA can be a:

- Tool to demonstrate regulatory compliance;
- Business efficiency tool to ensure product quality and minimise hygienic risks; and,
- Communication tool to customers and consumers, wherever they are in the world.

In providing these assurances they asserted that it is important to address both food safety (through demonstrating and communicating risk assessment and management) and quality (of the product and systems of production). The Interim Report on the Animal Welfare implications of Farm Assurance Schemes by the Farm Animal Welfare Council (FAWC, 2001) defined QA schemes as '*schemes that aim to satisfy consumers that stipulated standards relating to characteristics of a product are met during its production process.*' It is important to differentiate between QA "production" standards that define:

- Standards relating to the production of livestock, (including productivity, environmental management, worker welfare, animal health and welfare);
- Standards that relate to management of food safety risk; and
- Product standards that define the key attributes of a finished product.

Food safety criteria and also some elements of production standards are generally driven by legislative compliance, while finished product standards are usually defined either in a series of internationally agreed product standards and/or customer specifications and address criteria such as the proportion of added water, flavour, texture, nutritional value, cooking quality, size of breast fillets or presence/ absence of breast blisters and hock scab. Economic literature (Maze and Galan, 2000) introduces the concept of three types of standard depending on their functions:

- 1) Minimum quality standards i.e. product specifications;
- 2) Reference standards i.e. Codex Alimentarius Commission (CAC) or United Nations Economic Commission for Europe (UNECE) standards which are international recognised; and,

- 3) Compatibility standards i.e. International Organisation for Standardisation (ISO) Standards, Assured Chicken Production (ACP) standard.

This research has investigated the current status of the poultry industry with regard to the development of QA systems against the changing regulatory policy, market and consumer environment. The study has defined the current position with regard to evolving UK and EU legislation, world trade agreements and institutions, global trade in chicken meat and market QA standards. In the study, QA is taken to embrace legal and market driven standards for food safety and quality (Baines, 2001), along with production standards, including animal welfare (FAWC, 2001) and the environment (Baines & Davies 1999).

## **1.2 Benchmarking QA Approaches**

The nature of QA approaches varies by sector and according to the stage in the food supply chain; therefore it is important that this study developed a mechanism to compare these approaches. One method is to "benchmark" systems against each other to identify similarities and differences. The UK Policy Commission Report on the Future of Farming and Food, known as the 'Curry Report' (PC, 2002), highlighted benchmarking as a mechanism for identifying how a business is operating compared to others in the same sector. The report states that: 'the "Efficient Consumer Response" approach has been an effective means of driving down costs and improving efficiency in supply chains elsewhere in manufacturing and retailing. This approach requires the sharing of benchmarking costs and margin information, so that all parties thoroughly understand the economics of their industry. Through that understanding they can develop the best solutions to meeting consumer needs at the lowest costs.'

Outside of the food industry, Benchmarking was defined in 1979 by D.T. Kearns, Xerox CEO as: *"The continuous process of measuring our products, services and business practices against the toughest competitors or those recognized as industry leaders."* This implies that in order to stay competitive both individual organisations, and defined integrated supply chains, should consider benchmarking as a management tool to identify current and developing best practice, analyse production and supply chain costs and identify ways to reduce them further whilst identifying key customer requirements and ensuring that they are consistently met. The 'Curry Report' (PC, 2002)

goes further and considers that there is a link between adding value and the role of assurance schemes as follows: *'.... Assurance schemes are a potentially valuable way of communicating value to consumers. However, at the moment that communication is confused. There are too many schemes and consumers do not understand their implications.'* There is a valuable argument that schemes that do not require additional quality attributes above legislative requirements are not entitled to demand "added value". There are a number of assurance schemes that interface within the UK poultry meat supply chain (working paper thirteen). It is critical to the success of branding whether that be a manufacturers "brand"; a retailers "own - label" brand or a production standard logo such as the "Red Tractor -ACP" or "Freedom Foods" that the consumer can readily recognise the perceived "emotional" attributes as well as the tangible ones. These attributes may include:

- Confidence in the brand that it will deliver products of a specific standard and within a certain price range i.e. "own label" versus "value-own label" products;
- Trust of a brand name which means that as a consumer you will often pay more to be assured of purchasing a consistent food product which you "know" has specific attributes; and
- Wishing to "buy" into a perceived value such as fair-trade; environmental management or organic status; improved animal welfare; or improved nutritional quality or a prescribed nutritional value such as low-fat.

Given this market environment, it is reasonable to ask how individual organisations or discrete supply chains can seek to differentiate products and remain competitive in an increasingly global marketplace.

### **1.3 Research methods**

The research addressed a number of these themes, and identified how they could be applied to the poultry meat supply chain in order to underpin business viability in an increasingly regulated yet international market. Following the literature review, a QA model for the poultry meat supply chain was developed to address the need to have a viable, profitable industry whilst meeting the requirements of the various external stakeholders. The methodology used to develop and evaluate the model was:

- A literature review of current legislation, policy, market and consumer requirements i.e. a review of International, EU and UK legislation, evaluation of World Trade Organisation (WTO) rules for trade liberalisation, analysis of the development of international standards and its impact on poultry meat production;
- Data collection in the years 2000-2005 from the case study broiler site of performance against the key criteria identified during the literature review, discussions with industry and evaluation of current QA Schemes;
- Critical analysis of the current QA standards within the broiler supply chain and the development of a mechanism for benchmarking these standards to determine the degree of compliance with current legislation, international standards, market specifications and thus compare schemes to each other;
- Development of a series of questionnaires to determine internal and external stakeholder views;
- Face to face interviews to determine the key pre-requisites for a QA model with both internal and external industry stakeholders;
- Testing and evaluating the QA Model to determine its validity and value to the supply chain and consumers and whether it had the potential to meet the needs of both an individual broiler grow-out business and the integrated supply chain through industry evaluation and participation;
- Ongoing literature review to ensure that changes to legislation and/or policy were considered within the QA model;
- Semi-structured interviews with broiler producers to benchmark KPI and the development of a poultry growers benchmarking group to assess key performance criteria across the group and to determine, if possible, the degree of benefit to individual growers of being in a benchmarking group;
- Face-to-face interviews and focus group discussions on the QA model with external stakeholders and interested parties to determine the supply chain, national and global perspective; and
- Cost benefit analysis.

## 1.4 Content of the PhD Thesis

The work undertaken is presented in the thesis as follows: the first chapter introduces the research programme, hypothesis and the research strategies used to develop the QA model. The subsequent chapters then develop the themes of the PhD study. The Appendices Section includes:

- Analysis of case study data and appendices to the PhD Thesis; and
- Copies of published papers or papers accepted for publication produced as a result of this study.

The background to QA and the previous work in the area of quality management and the development of QA models is outlined in published papers (Manning and Baines, 2004a and Manning *et al.*, 2006a) and Appendix 9. The poultry producers' perspective on the benefits that they believe that QA has delivered is discussed by Manning *et al.*, 2007c.

Chapter Two supports the research published in papers (Manning and Baines, 2004b and Manning *et al.*, 2005) and paper ten. It addresses supply chain globalisation and the dynamics of contract poultry meat production and the potential for agroterrorism. The chapter analyses financial data from global organisations to determine both historic and current financial performance and potential developments. It also compares United States (US) and UK market trends and defines the business performance context in which the research model is functioning.

During the literature review the system externalities of legislation, harmonisation of global accreditation and international food standards were examined. International Food Standards have been reviewed (Appendix 8) to determine how they are cross-linked to QA standards, harmonisation of global accreditation, legislation and the mechanisms of global food supply. Appendix eight also defines current European and UK Legislation which impacts on the broiler supply chain. The scope of the legislation reviewed encompasses food safety, animal welfare, personnel health and safety and environmental management and conservation. The future impact of forthcoming legislation is also drawn together in Appendix 8.

During the literature review stage of the study, the principles of benchmarking and the development of KPI and their relevance to the poultry meat supply chain was considered. The



background to benchmarking in the food supply chain is discussed in paper nine. The development of quantitative, rather than qualitative, KPI for animal welfare (Manning *et al.*, 2007a), environmental performance and food safety (Manning *et al.*, 2006c), has been evaluated.

The development of the research model for the poultry meat supply chain is discussed in Chapter Three. The objective of Study A was to determine industry stakeholders' views on the KPI which they felt were important to measure. The objective of Study B was to determine the performance of the case study broiler site for the five years from 2000 – 2004 and relate those performance figures to published figures, identified as a result of literature review, especially those relating to environmental performance. The methodology for Study B and the results of the study are considered. The objective of the research model measurement is to determine the extent to which the broiler supply chain currently operates in compliance with the proposed research model; whether the research model will deliver regulatory and market compliance, and to develop benchmarking data for each KPI. The research model has been developed in two parts: the pre-requisite programme (Appendix 3) and the QA model (Appendix 4). The methodology for testing the QA model is also described. Poultry producers' views on the implementation of QA mechanisms in the poultry supply chain have also been discussed (Manning *et al.*, 2007c).

The results of the research model measurement are presented and discussed (Chapter Four) and the conclusions from the study are then drawn together in Chapter Five. The references are appended to the thesis.

## CHAPTER 2 – GLOBALISATION OF THE POULTRY SUPPLY CHAIN

### 2.1 Introduction

Increasing globalisation of the poultry meat supply chain has led to consolidation and the evolution of Transnational Corporations (TNC) whether by vertical or horizontal integration and the development of business clusters (Manning and Baines, 2004b). There are significant benefits in these economies of scale especially improved purchasing power and greater intellectual, technological and production resources for organisations to draw upon to provide products, which meet differentiated customer needs. The consumer has seen the benefit of globalisation in lower commodity food prices, wider product choice and the advent of “convenience” food. This chapter will consider how global governance impacts both on trade and food production with particular reference to the poultry meat sector. Globalisation, is defined by the Food & Agriculture Organisation (FAO, 2003) as the *'ongoing process of rapid global economic integration facilitated by lower transaction costs and lower barriers to movement in capital and goods.'* While Cable (1999) defines globalisation as, *'a mixture of international, multinational, offshore and global activities and involves a general progression from the domestic to the global.'* The development of organisational structures, trade policy and the development of contract farming is discussed by Manning and Baines (2004b).

Howells and Wood (1993) identified a number of ways in which environmental concerns affected sustainable global production (Manning and Baines, 2004b). This has led to organisations transferring their production to the least cost environmental locations. The need in the UK for regulatory compliance with EU Environmental Directives including Integrated Pollution Prevention and Control (IPPC), Animal By-products, Nitrate Vulnerable Zones (NVZ), Waste Management, and the Water Framework Directive has the potential to increase the costs of production and make UK and EU poultry meat uncompetitive in a global marketplace.

The EC Lisbon Summit of March 2000 developed the strategic goal by 2010 of the EU becoming: *“the most competitive and knowledge based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion”* (EC COM, 2002).

Corporate Social Responsibility (CSR) is a major strategy to ensure this goal is met with organisations integrating into a single policy the social and environmental concerns in their operations and their interface with internal and external stakeholders (Manning and Baines, 2004b). Increasingly TNC are being asked to allow access to information beyond financial reporting which demonstrates the organisations commitment and performance against social and environmental measures. The impact of the cost of social and welfare legislation on an organisation's competitiveness is a key factor in the developing global food market.

Global governance and the interrelationship between foreign direct investment (FDI), trade and sustainable development are key dynamics to CSR policy and the demands of both internal stakeholder (shareholder, employee or contract farmer) and those of external stakeholders for more sustainable investments, and compliance with internationally accepted standards and agreed instruments. The interest in CSR benchmarking for social and environmental performance has led to an increase in guidelines and codes of practice and also to social accountability being a pre-requisite for some QA standards. International instruments for labour management include the International Labour Organisation (ILO) core social accountability labour standard SA 8000, and the Ethical Trading Initiative (ETI) Base code. The market place has also seen an increase in fair-trade and ethical trade initiatives, third party auditing of organisations and labelling of food products. The development of ethical models has been discussed (Manning *et al.*, 2006b).

Agricultural trade policy is formed as a result of individual nation domestic policy and international trade agreements (Manning and Baines, 2004b). The WTO Uruguay Round defined a structure for trade dispute settlements and rules for foreign investments, recognising that FDI rather than trade is now driving globalisation and there was limited agreement on trade-related investment measures (TRIMS). The European Single Market was formed in 1992 and not only addressed the need to remove trade barriers but also to harmonise differences in national regulation. The impact of harmonisation of legislation in the EU on the poultry meat supply chain is further reviewed in Appendix 8.

Harmonisation of standards at both a global and/or regional level has continued to be addressed, for example, the ISO series and many industry-generated standards; and the Bank for International Settlements (BIS) banking standards. The requirements for food safety and the introduction of Hazard Analysis Critical Control Point (HACCP) based food safety risk management systems and the activities of the WTO in defining trade agreements needed to develop in tandem to prevent trade disputes into the future (CAC, 1997). The WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement), which came into force in January 1995, was aimed at minimising the negative effects of unjustified health barriers on international trade (Baines, 2001). At the 70<sup>th</sup> General Session of the World Organisation for Animal Health (OIE) a recommendation was adopted committing the OIE to take the lead on animal welfare (Manning and Baines, 2004b and Manning *et al.*, 2005). Harmonisation is one approach i.e. the mutual recognition of different national regulatory systems, another is deregulation. The Uruguay Round also resulted in a specific Agreement on Agriculture (AoA). The three pillars of the AoA are market access, domestic support and export competition (FAO, 2003). Knight *et al.*, (2002) described the aim of the AoA which has had a significant impact on the ongoing reform of the Common Agricultural Policy (CAP) and the further rounds of the WTO negotiations.

Financial barriers to trade have been defined (Manning and Baines, 2004b). Regional trade agreements (RTA) have also had an influence on freedom of trade and include the EU; North American Free Trade Agreement (NAFTA) between Canada, Mexico and the US; and the Mercosur between Argentina, Brazil, Paraguay and Uruguay; the Association of South-East Asian Nations (ASEAN) and the Asian Free Trade Group (AFTA). The organisational focus of vertical supply chains and individual primary producers or producer groups is changing under the influence of food supply globalisation. Aho (1998) defined the impact of globalisation on the current and future structure of primary production. This research has been adapted to the context of this study (Manning and Baines, 2004b). The agricultural economy is increasingly characterised by the greater concentration, or intensification, of farms with the rising influence of contract farming and the evolution of integrated supply chains linking producers and consumers (Opara, 2003). The poultry supply chain includes both inter and intra organisational trade in live poultry, poultry meat,

eggs, feed and waste/byproduct disposal. Organisations that are involved in poultry production include:

- Producers and processors – e.g. farms, hatcheries and processing factories;
  - Suppliers of goods and services – e.g. feed, feed supplements, medication, veterinary advice, transportation and distribution, waste disposal, technical support, import/export agency and insurance; and
  - Purchasers of poultry products e.g. retailers, food service, poultry fertiliser, pet food
- (Adapted from BCI, 2006).

Hagelaar and van der Vorst (2002) suggested that the supply chain is a network of multiple businesses and relationships.

Increased supply chain globalisation has led to an increased risk of the spread of pathogenic bacteria and zoonoses present in meat and also the potential for the global spread of animal disease including livestock viral disease such as Foot and Mouth Disease (FMD), Newcastle Disease (ND) and Avian Influenza (AI). The economic impact on international, national and individual organizations in the event of an outbreak of a notifiable disease is potentially devastating (Manning *et al.*, 2005). Individual Governments and TNC must have policies in place to ensure the health and safety of the human population and also to protect animal health and welfare.

From late 2005 to early May 2006, AI outbreaks have been reported in approximately 40 previously unaffected countries (FAO, 2006). A number of these countries are either major poultry consuming or importing countries. Globalisation of food trade means that an inability to respond to a food emergency could have significant consequences on health and trade in many countries (WHO, 2002). The potential effects of an AI outbreak such as H5N1 have been described (BCI, 2006) and include lower poultry meat consumption either temporarily or in the long term because of health concerns amongst the general public; lower demand because the general public do not believe government and food industry assurance that the food is safe; reduced availability because of large losses of poultry so that demand can not be met; and loss of organisations and/or organisational structures due to the closing down of trade between geographic regions or

individual supply chains. Economics losses caused by animal diseases such as AI have been categorised (Van Asseldonk *et al.*, 2006) as either direct or consequential (indirect) losses. Direct losses would be those incurred as a result of implementing the disease eradication programme, for example, the financial value of the livestock involved and the costs incurred in disease control and monitoring the farms in the controlled geographic areas around the initial outbreak(s). Consequential losses can be described as those costs incurred as a result of movement restrictions and/or trade or market disruption. Van Asseldonk *et al.*, (2006) sub-divided these into five further categories price effects, business interruption, losses related to established movement zones, repopulation of the farm; and losses from emergency vaccination. Furthermore, they argued that the consequential losses of the Dutch 2003 AI epidemic exceeded three to four times the direct costs largely because 50% of the poultry population was pre-emptively slaughtered. These losses were borne by the Dutch poultry supply chain rather than being covered by government funding. Verbiest and Castillo (2004) differentiated the impact of a disease outbreak as being either macroeconomic or microeconomic. They argued that the macroeconomic impact of a disease outbreak such as AI might be limited where the poultry industry remains small in terms of a country's gross domestic product (GDP). For example, they determined that animal husbandry represented 8% of GDP in China and 0.4% of GDP in Thailand, therefore GDP underestimated the overall economic impact of the livestock industry and that the contributions of industries such as packaging, animal feed production and animal breeding should also be considered. However, whilst the direct impact on GDP may be small, they suggested as have Van Asseldonk *et al.*, (2006) that there is an indirect longer term effect namely the microeconomic impact.

Poultry production regions can be classified on the basis of the degree of risk of an AI epidemic (Van Asseldonk *et al.*, 2006). The authors suggested that the following criteria should be used:

- The natural borders of the region e.g. rivers, mountains, seas;
- The number of live animal imports/exports (including breeder egg sales);
- The density of poultry flocks; and
- The level of biosecurity/sanitary controls and hygiene measures.

Disease related interruptions of trade flow affect not only the exporting country but also the importing country especially when the meat affected by the trade ban cannot be fully replaced

either by domestic producers or by other exporting countries or, as previously described, where consumer demand is reduced (Blayney *et al.*, 2006). The economic impact will depend upon the time duration of the outbreak and whether the outbreak remains solely an animal disease (Verbiest and Castillo, 2004). Blayney *et al.*, (2006) suggested that the degree of financial impact depends upon three key criteria:

1. The relative importance of meat exports to producers in the affected country (this would also include as previously described eggs, and poultry production by-products). If meat which has historically been exported must then be sold on the domestic market it will reduce prices;
2. The proportion of imports that originate from one country or geographic area. If supply is abruptly halted by an exporter and the volume of supply constitutes a high proportion of total imports in another country this will impact on trade flow if it cannot be timely replaced by a third party; and
3. If the animal disease poses either a perceived or a potential threat to humans (Blayney, 2005).

Another major factor which will determine the impact on meat exports in the event of an AI outbreak is the proportion of exported meat products which are further processed and cooked as opposed to raw meat. In countries such as Thailand there has been a major restructuring of the industry from chilled/frozen products to prepared cooked meats since the advent of AI. Brazil overtook the US to become the world's largest exporter of poultry meat in 2004 but this trade is largely uncooked product and is therefore vulnerable to an AI outbreak. The trade in bone-in brown meat has also been disrupted. Countries such as the US have historically exported brown meat to Asia, but if the export demand is low, for the reasons previously described, then this meat has a limited home market with the resultant downward pressure on price.

Goldsmith *et al.*, (2002) compared the US and EU supply chains and argued that the US chain focused on price, labour and distribution efficiency and product performance in areas such as shelf life, trim and retail readiness, leading to a supply chain that was commodity driven and based on scale. In contrast, they observed that the European supply chain was undergoing significant structural change and was seeking to primarily provide a traceable product which was source

verified. The authors questioned whether European packers were at a competitive disadvantage because of investment in control systems with higher capital and transaction related costs, or if US producers would be at a global competitive disadvantage because they had focused on the intrinsic and extrinsic quality requirements of the domestic, rather than export, market.

Within this regulatory and market context, individual Governments and TNC are required to undertake formal risk analysis and have resultant policies in place to ensure the health and safety of the human population, protect animal health and welfare and also minimise the potential for trade disruption and/or economic loss (Manning and Baines, 2004b). Scientific or accountancy based risk assessment is a distinctly different activity from ethical or moral risk assessment. Slovic (2000) stated that "*the perception of and acceptance of risk have their roots in social and cultural factors*". These factors will vary from country to country and organisation to organisation. In assessing the various types of risk whilst traditional risk factors are important, investor risk is also a major market driver. Maintaining shareholder confidence is key for a TNC to ensure continued investment that will to sustain business planning and operational activities and past investment risk does not guarantee future investment risk (Jaegar, 2006). He proposed that the factors that need to be considered to determine investment risk include organisational, market and non-market related factors. Credit risk is an important aspect and in capital markets credit ratings will influence investment decisions. Moody's Investors Service, for example, provides credit ratings, research and risk analysis for the international capital markets with a globally consistent framework for comparing the credit quality of rated debt securities (Moody's, 2006). A rating is Moody's opinion of the credit quality of individual organisations or of an issuer's general creditworthiness. Investors use the ratings in the development of an investment portfolio and they provide issuers of debt with stable, flexible access to sources of capital. Therefore Moody's credit ratings represent a rank-ordering of creditworthiness, or expected loss. Whilst such rating summarises the credit risk it does not define who will actually default in the future, rather the credit risk categories that statistically will default at a particular frequency. These ratings are divided into two sections, investment grade and speculative grade. The rating scale runs from a low credit risk of Aaa to a high risk of C, with 21 categories in the rating scale (Figure 2.1).



Long term		Short Term			
Investment Grade	Aaa	Prime 1			
	Aa1				
	Aa2				
	Aa3				
	A1				
	A2	Prime 2			
	A3				
	Baa1				
	Baa2			Prime 3	
	Baa3				
Speculative Grade	Ba1				Not Prime
	Ba2				
	Ba3				
	B1				
	B2				
	B3				
	Caa1				
	Caa2				
	Caa3				
	Ca				
	C				

**Figure 2.1: Moody's rating system (Adapted from Moody's, 2006)**

The market has seen a build up of poultry meat stocks and a general price decline (Table 2.1). From 2005 to 2006 there has been a reduction in poultry production of 1.1% and a reduction in poultry trade of 3%. There has been a lack of growth in the EU poultry meat market over the last five years (Table 2.2). The figures include all poultry meat production and not just chicken meat. Whilst most EU national outputs remain stagnant it is only Germany and Poland that have experienced growth since 2001 with the French industry contracting quite significantly (Poultry World, 2006).

**Table 2.1: World poultry meat statistics (Source: FAO, 2006)**

**Table 2.2: EU Poultrymeat output ('000T) (Source: Poultry World, 2006)**

Within the UK chicken meat industry there has been a rise in production output from 2001 – 2005 of 5.2% from 1.21 to 1.28 million tonnes, and producer prices have fluctuated between 47.9 and

50.3 p/kg liveweight with an increase between 2001 and 2005 of only 1.4% (Poultry World, 2006). Sheppard and Edge (2006) undertook a study in the UK in 2005 which built on earlier work in 2002 and determined the financial return for producing a broiler meat chicken in spring/summer 2005. The cost which had increased most significantly was energy costs. It was estimated that the financial return was a margin of 1.9 pence/bird in 2005 compared with 3.0 pence/bird in 2002. Analysis of the UK poultrymeat supply balance demonstrates that between 1995 and 2004 poultry imports rose by 90% however in 2005 import levels fell to below those in 2003 (Poultry World, 2006). Producer prices remained largely unchanged due in part to an increase in national output and a reduction in export levels. In the US, cold storage data for chicken meat from June 2005 – June 2006 showed a rise in stock holding from 901 million lb in June 2005 to 1151 million lb in January 2006. The subsequent reduction in stock holding from January 2006 to June 2006 saw a fall to 1002 million lb (Table 2.3).

**Table 2.3 US Cold Storage Data June 2005 – June 2006 (Source: Pilgrim's Pride, 2006)**

Given these market and legislative externalities, the research has sought to ascertain if their impact can be demonstrated in recent financial performance within the global poultry meat supply chain.

## **2.2 Supply chain dynamics**

The financial performance of TNC was discussed by Manning and Baines (2004b). Further research has been undertaken to assess financial performance subsequent to the original paper being written. The conclusions from this research are now discussed for six processing/manufacturing organisations: three from the US, Tyson Foods Inc., Conagra Foods Inc., and Pilgrim's Pride Inc., and three from the UK, Grampian Country Food Group Ltd, Northern Foods plc and Rank Hovis McDougall (RHM) Foods plc. Analysis of UK retailer performance is also undertaken.

### **2.2.1 Tyson Foods Inc., (US)**

The sales figures and operating income for 2001 - 2006 have been analysed based on Tyson Foods annual reports, and show that although sales have increase year on year (YOY) since 2000, mainly due to the acquisition of Iowa Beef Processors Inc., (IBP), the annual gross profit has reduced over the same period from 12.9% in 2000 to 6.7% in 2005. The net income as a percentage of sales has stayed fairly static in years 2002 – 2005 (1.4 – 1.6%). This may well reflect the continuing pressure on margins in the meat sector at retail and food service level and the cascade effect through the supply chain. The figures reported are influenced by beef, pork, chicken and prepared food sales. Beef sales especially have seen a sharp downturn in profitability in the years 2002 to 2005 in part due to the impact of Bovine Spongiform Encephalopathy (BSE).

The figures for the poultry segment have been extracted (Table 2.4) and demonstrate that in the years 2000 – 2005 the average operating profit as a % of sales for the chicken segment has been 5.0%. Whilst the overall financial performance for 2006 has been reported as a net loss of \$293 million compared to a profit of \$528 million in 2005, the performance of the poultry segment fell from a profit of \$582 million in 2005 to \$53 million in 2006 (Tyson, 2006). During the 2006 financial year Tyson Foods announced a range of cost cutting measures designed to save around \$200 million within the year. These measures included reducing staffing levels especially in middle management and management support, minimising recruitment and reducing consultancy fees, relocation costs and sales related expenses (MeatPoultry, 2006). The reasons put forward for this action were market volatility and an excess amount of protein in the US. Moody's Investment Service has downgraded the senior unsecured rating for Tyson Foods Inc., from Baa3 to Ba1 this reflects the deterioration of Tyson's operating performance and debt protection measures and the challenge of cost reduction (MeatPoultry, 2006).

**Table 2.4: Chicken Segment Financial Figures from Tyson Foods Inc., 2000-2006 (Source: Tyson, 2006)**

If the credit rating falls further, this could potentially affect the ability of Tyson Foods Inc., to finance their current debt levels.

### **2.2.2 ConAgra Foods Inc., (US)**

In June 2003, ConAgra Foods Inc., sold its chicken division to Pilgrim's Pride Inc., with a resultant reduction in sales from 2003-2005 (Table 2.5). Therefore the organisational focus has changed to the supply of food ingredients, food service and retail products. Financial results reported for the 26 weeks ending November 27<sup>th</sup> 2005 and November 28<sup>th</sup> 2004 have been examined (Table 2.6).

**Table 2.5 Financial Figures from Conagra Foods Inc., 2002-2005 (Source: Conagra, 2005)**

**Table 2.6 Financial Figures from Conagra Foods Inc., 2004-2005 (Source: Conagra, 2006)**

The results indicate a fall in sales YOY of 3.0% with a fall in operating profit of 7.2% of which 10.6% of the decline is in retail products, demonstrating the pressure on margins in the food supply chain. ConAgra Foods Inc., reported a \$31.7 million loss for their third quarter ending in February 2006 which compared with a net income of \$163.3 million in the previous year's third quarter despite an increase of 4.4% in net sales. The loss was attributed to restructuring and various other impairment and litigation costs. In January 2006 Moody's Investment Service also downgraded the long-term debt rating for ConAgra Foods Inc., from Baa1 to Baa2 due to the decline in operating income from the refrigerated meat business. For the 52 weeks ending May 28<sup>th</sup> 2006 ConAgra Foods Inc., reported an increase in sales of 0.7% but a reduction in operating profit of 5.4% YOY (Conagra, 2006). ConAgra Foods Inc., have announced that they plan to divest most of their refrigerated meat business and implement further changes to streamline its operations (MeatPoultry, 2006).

### **2.2.3 Pilgrims Pride Inc., (US)**

When ConAgra Foods Inc., sold its chicken division to Pilgrim's Pride Inc., for \$590 million to form the second largest U.S chicken company, with an annual net sales of approximately \$5 billion, O.B Goolsby, president and chief operating officer of Pilgrim's Pride Inc., stated that, *"Our increased size and scale will also give us the ability to compete more effectively in a consolidating marketplace and further enhance the technological leadership and cost-efficiency for which we are known."* (MeatPoultry, 2006) This quote summarises the driving forces which are behind the global model. Pilgrim's Pride Inc., financial figures demonstrated (Table 2.7) a downward trend in operating profit from 2001 – 2003. However from 2003 to 2005 there was a significant rise in operating profit. The business has during this time period developed the added value rather than the "commodity" frozen product sector of their business. In the context of the global spread of H5N1 AI, Pilgrim's Pride Inc., issued amended guidance on its financial forecast for the second quarter of 2006 (Pilgrim's Pride, 2006). This stated that the selling price for chicken leg quarters had declined from an average selling price of \$0.33 per pound in the first quarter of fiscal 2006 to approximately \$0.15 per pound. Whilst the Mexico operations had broken even in February 2006 in the same period the U.S. operations had sustained a net loss of approximately \$15 million. By

the third quarter there was an operating loss in both regions. Pilgrim's Pride Inc., who has a Moody's Investment Service rating of Baa2, said that the loss was largely due to weak pricing and high inventory levels (MeatPoultry, 2006) and have implemented a programme of cost reductions and focused on improving efficiencies.

**Table 2.7: Financial Figures from Pilgrim's Pride Inc., 2001-2006 (Source: Pilgrims Pride, 2006)**

#### **2.2.4 Grampian Country Food Group Ltd (UK)**

Grampian Country Food Group Ltd is the biggest U.K poultry producer and was the 12<sup>th</sup> largest global meat company in 2003 (MeatPoultry, 2006). Analysis of the financial figures from Grampian Country Food Group Ltd financial statements 2000-2005 have been collated (Table 2.8). The information from their financial reports would indicate that although the company's sales revenue is increasing (also in part due to acquisitions) there is a pressure on margins and operating profit as a percentage (%) of sales having fallen from 3.4% in 2001 to 1.3% in 2005. The figures do not differentiate between sales of poultry, pork, beef or lamb so it has not been possible to analysis the operating profit of the poultry segment of the business directly. In the UK, the increasing cost of compliance with environmental legislation including IPPC and animal by-product disposal has meant that there is a legislative driver for the industry to move live bird production to the commodity whole bird and portion market rather than manufacturing deboned meat products.

**Table 2.8: Financial Figures from Grampian Country Food Group Ltd 1999-2005 (Source: GCFG, 2006)**

The competitiveness of the cost of labour in the UK has also has influenced this trend. However in May 2006, Grampian Country Food Group Ltd reduced their UK output by around 40 million birds a year, 5% of the total UK output, also reducing the numbers employed at two factories (Poultry World, 2006).

### 2.2.5 Analysing the UK Supply Chain

Financial data from the four organisations previously discussed has been summarised (Table 2.9) with those from Northern Foods plc and RHM Foods plc. They demonstrate a significant variance in operating profit between the US and UK supply chain, this could in part be due to accounting methods. The influence on profitability in 2006 of H5N1 AI can be demonstrated with a negative performance reported for Tyson Foods Inc., and Pilgrims Pride Inc.,.

**Table 2.9: Analysis of Operating Profit as a Percentage of Sales 2000 - 2006**

	Operating profit (% of sales) 2000	Operating profit (% of sales) 2001	Operating profit (% of sales) 2002	Operating profit (% of sales) 2004	Operating profit (%) of sales) 2005	Operating profit ( % of sales) 2006
Tyson Foods Inc.,	4.6	3.5	5.9	6.5	7.0	0.7
Conagra Foods Inc.,	-	-	8.9	12.3	11.5	-
Pilgrim's Pride Inc.,	-	9.7	6.5	9.1	13.1	5.7
Grampian Country Food Group Ltd	1.0	3.4	2.1	1.7	1.3	-
Northern Foods plc	-	8.9	8.6	6.9	7.1	-
RHM Foods plc	-	-	-	4.3	10.1	-

US organisations have seen an overall rise in operating profits as a % of sales but Grampian Country Food Group Ltd has not realised equivalent trading performance. In order to determine if this is due to organisational performance or a trend in UK supply chain performance compared to US the operating performance of Northern Foods plc and RHM Foods plc has also been analysed (Table 2.10 and Table 2.11). Both RHM Foods plc and Northern Foods plc operate in the area of added value rather than commodity foods.

**Table 2.10: Financial Figures from Northern Foods plc 2001-2005 (Source: Northern Foods, 2006)**

Northern Foods plc is one of the UK's leading food producers employing around 20,000 people with a turnover of £1.45 billion. The company has both own-label market share, and has leading brand positions in frozen pizzas, premium biscuits, vegetable grills and pork pies. When compared to the other organisations (Table 2.10) Northern Foods plc demonstrates a slight decline in operating profit as a percentage of sales in 2004 and 2005.

**Table 2.11: Financial Figures from RHM Foods plc 2003-2005 (Source: RHM, 2006)**

RHM Foods plc is one of the largest food companies in the UK and Ireland and its portfolio of brands includes Hovis, Mr Kipling, Sharwood's and Bisto. The RHM figures indicate that although YOY sales have declined, the operating profit in 2005 has increased. Financial results reported for the 26 weeks ending October 29<sup>th</sup> 2005 and October 30<sup>th</sup> 2004 have been assessed and the results indicate an increase in turnover of £2.5 million and an increase in operating profit margin YOY of 0.6% to 9.5% (RHM, 2006). The financial results discussed suggest that those manufacturing/processing organisations adding value to their products, i.e. moving out of the commodity food market, can potentially maintain or increase operating profit as a percentage of sales. Although the supply chain can carry a reduction in margin for a period of time, it will ultimately impact, depending on an individual organisation's capital reserves, on profitability, cash flow, ability to meet any loan repayments and continue capital investment plans and then actual business and supply chain viability. The increasing costs of implementing new legislation will also impact on supply chain viability as this too will further reduce the margin.

### **2.2.6 UK Retailer Financial Performance**

Retailer performance has been assessed in the UK supply chain for Tesco plc, J Sainsbury plc and Wm Morrison Supermarkets. It should be noted that the financial data analysed does not differentiate between the individual performance of food and non-food sectors, therefore overall performance has been recorded. The financial data demonstrates that although Tesco plc performance remains robust with YOY increases in sales and operating profit (Table 2.12), J Sainsbury plc has experienced a reduction in sales revenue and latterly in 2005 a reduction in



operating profit as a percentage of sales (Table 2.13). Wm Morrisons Supermarkets announced in March 2006 a first ever full-year loss of £313 million. The pre-tax profit excluding the costs of taking over Safeway was £61.5 million, 81% lower than the previous financial year (£322.2 million) (ITN, 2006). It is in this context with regard to retailer and processor financial performance, that the QA model has been tested.

**Table 2.12: Financial Figures from Tesco plc 2001-2005 (Source: Tesco, 2006)**

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**Table 2.13: Financial Figures from J Sainsbury plc 2001-2005 (Source: JS, 2006)**

**2.2.7 The rural economy**

Within the rural economy a poultry integrator plays a significant role. The impact on a rural community if production were to move overseas (if for example, the UK proves uncompetitive viz a viz the cost of production in other global regions) is not only the loss of direct employment in the factories, feed mills, and hatcheries, but also indirect employment including transport companies, contractors, servicing companies and contract producers that grow the birds for slaughter. A number of allied Small and Medium sized Enterprises (SME) provide services to the private growers including veterinary practices, waste disposal, equipment suppliers, electricians, servicing contractors, cleaning teams, and pest control contractors. Many of the inputs to the contract production sites are supplied by local farmers via the feed mills including wheat, cereals and pulses. The poultry litter from the sites also provides a valuable resource as an organic nutrient to local farms. As with other industries, local economic consequences do not generally influence the decision to move production to areas of lower cost

## **2.3 Conclusions**

Integration within the poultry supply chain has led to the development of power bases at integrator and retailer level with a dependence on technology and administrative resource to drive such strategies as centralised buying and product distribution. This has led to an increase in costs which to date have been met by expansion and increasing business turnover often being financed by external capital sources. The increasing costs of implementing additional food safety, welfare and environmental legislation and market requirements as well as the direct, or indeed indirect, costs of a disease outbreak also influence supply chain viability. Although the supply chain can carry a reduction in margin for a period of time it will ultimately impact on organisational and supply chain viability. The financial results demonstrate the extent of consequential losses that can occur as a result of market fluctuation, disruption and the impact of supply exceeding demand either as a result of over supply or a loss of consumer confidence in traded products. Therefore one of the greatest influences on the future financial stability of the poultry meat supply chain is that of perceived investment risk and the ability of the organisations to service their long-term debt liabilities.

The literature has defined two distinct models of poultry production namely the European supply chain model which seeks to supply product with both intrinsic and extrinsic quality and the US model of commodity production and suggested that the ability to remain globally competitive will continue to challenge the global poultry meat supply chain and lead to a re-evaluation of the current global model and how it can continue to operate in the current and future market environment. In order to drive continuous improvement in the performance of the supply chain a Total Quality Management (TQM) approach should be implemented. This mechanism will identify current methodology and processes utilised and any changes to current practices, which could minimise “out-of-specification” production at any stage in the supply chain. This requires the development of a fully communicating and blame-free culture within the supply chain and the development of KPI at all stages to monitor the performance of the supplier-customer-supplier-customer supply chain. The next chapter develops this theme further and discusses the development of the research study.

## **CHAPTER 3 – THE DEVELOPMENT OF THE RESEARCH MODEL**

### **3.1 Introduction**

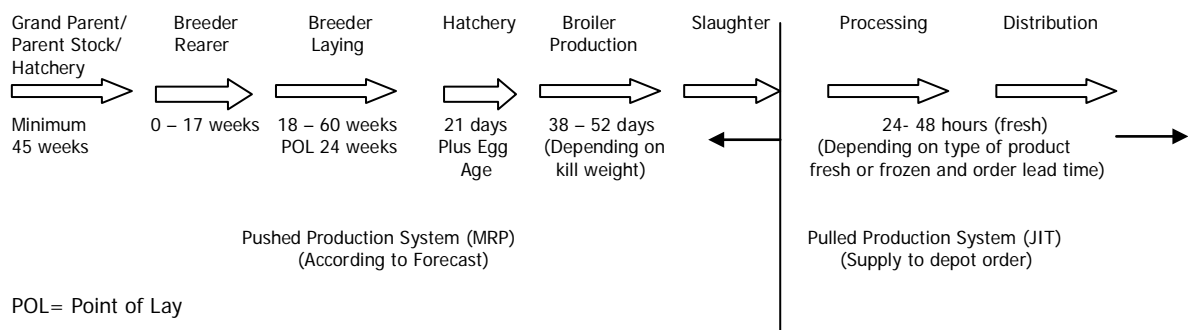
Current mechanisms of globalisation (Manning and Baines, 2004b) can lead to a competitive disadvantage if there is no differentiation between products at retail level where there is a need to comply with national legislation or market drivers which add significantly to the cost of production compared to other global producers/markets. The literature review suggests that the market, which UK poultry meat industry are increasingly seeking to supply, is narrowing to the fresh meat market, as the UK is now uncompetitive in other poultry product sectors. The business model developed as a result of this study is primarily developed for the whole bird market, however it has application to all sectors of the poultry industry.

In order for the QA model to drive legislative compliance and business performance, the key quality attributes of the sector needed to be defined. In the fresh meat market these include bird weight and weight uniformity across the flock as well as carcass conformation and breast meat yield, fat levels according to specific market needs such as oven ready, cooked or further processed products, skin colour, meat texture and flavour. The level of contact dermatitis is a recognised indicator of bird welfare (Manning *et al.*, 2007a). In the whole bird market rather than the deboned meat sector it also influences carcass quality. The literature review, market analysis undertaken and discussions with stakeholders has led to the development of KPI, which quantify many of these quality attributes whilst also providing data to evaluate legislative compliance and business performance.

### **3.2 Commercial constraints on the poultry supply chain**

The development and types of supply chain QA model have been previously discussed (Manning *et al.*, 2006a). Minegishi and Thiel (2000) produced a causal diagram for a poultry carving enterprise (Appendix 1). The model uses the concept of feedback loops and causal effect to build an organisational network. This diagram demonstrates the complex interactions that affect the poultry meat supply chain. It is essential therefore when developing a QA model to determine the interaction of the chain and the criteria that need to be measured to monitor supply chain

efficiency and potential areas for improvement. The development of a Just-in-Time (JIT) production system is essential where organisations are seeking to reduce costs such as material and product storage costs. The factors which impact on the fresh meat production cycle include: short shelf-life of finished product; economic size of production runs and the balance between production forecasting and actual order quantities as well as the need for traceability to and from source. It was therefore argued by Minegishi and Thiel that this system is a “pulled production system” for the processor and a “pushed production system” for primary production where the product supplied (birds) could vary both qualitatively and quantitatively. The logistics of the broiler supply chain can be divided into a number of phases as defined (Figure 3.1); the timescales at each stage vary considerably (Manning *et al.*, 2006a).



**Figure 3.1: Logistic supply chain of broiler production (adapted from Minegishi and Thiel, 2000)**

This study has defined some of the commercial constraints on the poultry meat supply chain, which include:

- The actual finished weight of the bird is critical to optimising breeding and growing costs at p/bird, p/m<sup>2</sup>/wk or p/kg of liveweight;
- Bird health, feed quality, house environment and adverse weather conditions will affect bird performance and the potential to reach optimum weight and the liveweight (kg) produced per birdplace/cycle or birdplace/year or kg/m<sup>2</sup>/wk or kg/m<sup>2</sup>/yr. These factors will also affect the cost of production in terms of raw material (feed and chick) and energy costs;
- The variation in weight within a given flock of birds. Water quality, feed quality, chick quality, weather conditions, internal house environment or a disease challenge, could affect the consistency of weight across a flock of birds. Therefore birds do not meet

specification in terms of carcase or portion size/weight. This is not so critical with birds destined for the deboned market (when all meat is removed from the bone e.g. nugget or Kiev type products or ready meals), but is a major factor when growing birds for the fresh or whole bird market;

- The “crop” of live birds has to be processed within a specific time frame; otherwise there are potential welfare implications. The birds programmed on any given day of slaughter may have been originally placed on a forecast sixty-six weeks before. The programme may be severely affected over that time with disease challenges, or adverse weather conditions that could affect the breeding or broiler stock. However, there are internal mechanisms to manage variations in the system such as disposing of breeding eggs/chicks if the forecast is too high, or buying in eggs or day old chicks if there is a shortfall;
- Daily planning in the processing plant will need to be adjusted to compensate for birds not meeting key criteria on arrival or changes to the projected orders; or for low numbers of birds due to increased mortality as a result of a disease outbreak or other incident;
- Processing is further complicated in that the depot orders may not be for whole birds but for a variety of portion configurations, thighs, wings, drumsticks, breast meat and/or further processed products. The orders received from customers will not necessarily equate exactly to whole birds being slaughtered. This may mean that excess portions need to be frozen down and sold through low margin markets;
- Indeed the daily orders may not relate to sales forecasts due to changes in consumer purchasing compared to the predicted trend. Poultry meat purchase has peaks throughout the year. For example, barbequing sees a rise in poultry meat consumption. This is forecast at certain periods through the late spring/summer but actual weather could affect sales. Thus birds that have been placed on farms to meet the potential demand do not have a market. This may mean that excess meat needs to be sold through low margin markets.

The performance of an intensive poultry unit will be driven largely by the kg of meat produced per m<sup>2</sup> and the optimising of the cost of producing that weight of meat. Historically, mechanisms for measuring business performance have included Feed Conversion Rate (FCR) and European

Production Efficiency Factor (EPEF) but the research model seeks to also use cost driven analysis such as returns per bird, per kg live weight or per m<sup>2</sup> (see Section 4.3).

### 3.3. Design of Study A

#### 3.3.1 Methodology

Study A was conducted in November 2003. The objective of Study A was to determine industry stakeholders' views on the KPI they felt should be measured in a QA model designed to drive performance against food safety, bird welfare, environmental and business performance standards. The factors specific to bird welfare and business performance are identified (Table 3.1). To facilitate this measurement a questionnaire was compiled (Appendix 2) which was developed as a result of comparative benchmarking of differing poultry QA schemes (Appendix 9).

**Table 3.1: Integrated performance indicators for bird welfare and business performance**

Parameter	Measurement	Parameter	Measurement
Mortality (Total, 7 days, 14 days or late)	Calculation (%)	Hen performance	Eggs per bird
Dead on Arrival (DOA)	Calculation (%)	Egg weight	Measurement (grammes)
Crop Length	Days	Hatchability	Calculation (%)
Fallow Period	Days	Breeder growth uniformity	Measurement (%CV)
Pododermatitis	Calculation (%)	Sexing accuracy	Measurement (%)
Leg culls	Calculation (%)	Lighting	Measurement (Lux)
Breast Blisters	Calculation (%)	FCR or EPEF	Standard Calculation
Bristol Gait Score	Standard Procedure	Growth Rate	Calculation (%) or uniformity (%CV)
Water Usage (Drinking)	Calculation (L/bird place/yr) or (L/bird/cycle)	Internal house Air quality	Measurement (% or ppm)
Veterinary Medicine Usage	Calculation (kg/yr)	Min/Max House Temperatures	Measurement (°C)
Water Potability	Laboratory Test (Micro. counts and nitrate levels within spec)	Min/Max Relative Humidity	Measurement (%)
Site Hygiene Swabs	Laboratory Test (Counts within specification)	Energy Usage	Calculation (kWh/bird sold), (wh/bird/day), (kWh/kg meat sold)
Feed Quality/ Suitability	Feed Analysis -compliance with standard	Stocking Density	Calculation (kg/m <sup>2</sup> ) or (birds/m <sup>2</sup> )
Feed efficiency	Feed Cost per kg liveweight or per m <sup>2</sup>		

It was deemed important to translate the legislative and QA model standards to practical standards and measurable performance indicators. Twenty-two respondents replied to the questionnaire in which they were asked to rate eighty-two performance standards on whether they should be included in a QA model for the poultry meat supply chain. Table 3.2 gives an analysis of the stakeholder group. The respondents were also asked to identify the ten KPI for their stage in the supply chain and list in order of importance. This gave an indication of the

industry attitude on the most valuable KPI. The respondents were also asked to give their opinion on a series of statements with regard to QA and benchmarking (Manning *et al.*, 2007c).

**Table 3.2: Analysis of stakeholder group**

Sector	Number of respondents
Veterinarian	2
Broiler Breeder/Hatchery	2
Broiler Growing	18

This latter exercise was repeated in January 2006. The overall reaction was very positive, achieving a 41 percent response rate in the first survey (n=22) and a 77 percent response rate in the second survey (n=23). This is deemed acceptable, given that postal questionnaire response rates are on average between 15 and 20 percent (Carroll, 1994).

### 3.3.2 Results

Fifty-four performance indicators were chosen by the respondents in November 2003; the thirty performance indicators most frequently identified are detailed in Table 3.3.

**Table 3.3: Analysis of the key performance indicators identified by respondents**

Indicator	No of respondents	Indicator	No of respondents	Indicator	No of respondents
FCR	16	Environmental conditions/air quality	7	14 day mortality	3
Growth rate	14	Biosecurity/ site hygiene swabs	6	Dead on arrival	2
Total mortality	13	Energy usage	6	Foot pad lesions	2
Feed usage	9	Water consumption/usage	6	Raw material usage	2
EPEF	9	Feed quality/suitability	6	Salmonella litter testing	2
Stocking Density	8	Water quality/potability	6	Carcase antibiotic residues	2
7 day mortality	8	Crop length	5	Sexing accuracy	2
Late mortality	7	Lighting programmes/intensity	4	Hatchability	2
Leg culls	7	Fallow period	3	Breeder growth uniformity	2
Veterinary medicine usage	7	Min/max house temperatures	3	Hen performance	2

The results demonstrate that a number of the performance indicators recognised in the literature review (Manning *et al.*, 2006c) are also identified as important to consider by the stakeholders who responded in this study. The KPI developed in the QA model seek to comply with these requirements. It was determined that due to research constraints the QA model would only be tested at the broiler growing phase on commercial growing units. The decision to use commercial units was firstly because the research would determine any practical limitations to the

implementation of the QA model, and secondly this was the sole source of data available. However, it has been accepted that using commercial units could potentially limit the scientific robustness of the study and this factor has been taken into consideration during the analysis of results and the subsequent discussion. The QA model indicators which have been investigated in the study are shaded in Table 3.13.

### 3.4. Design of Study B

#### 3.4.1 Methodology

The objective of Study B was to determine the performance of a commercial case study broiler site for the five years from 2000 – 2004 and relate those performance results to published literature, particularly research relating to environmental performance. The case study site was a four house 6022 m<sup>2</sup> site established in 1995 with a nominal 115,000 bird places. The growing programme used was “sexed” rather than “as hatched” and in each house the birds were placed in two pens. The pullets were thinned around 38 days and final clearance was at 52 days.

#### 3.4.2 Results

The placement figures indicated that there was a steady reduction in the number of birds placed (Tables 3.4 and 3.5). The data from the case study site complies with the “Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs (2003)” otherwise known in this thesis as “IPPC BREF”. The European IPPC Bureau exists to catalyse an exchange of technical information on best available techniques under the IPPC Directive 96/61/EC and to create reference documents (BREFs) which must be taken into account when the competent authorities of Member States determine conditions for IPPC permits. The BREFs provide information about what may be technically and economically available to an industry in order to improve their environmental performance.

**Table 3.4: Bird placement on case study site**

	Birds placed	Birds placed 2004	Birds slaughtered	Birds slaughtered 2004
Crop cycles analysed (number)	30	6	30	6
Mean birds/ m <sup>2</sup>	19.58 (SD 0.91)	18.69 (SD 0.30)	18.83 (SD 0.80)	18.03 (SD 0.27)
Average weight (kg) (*thinning process)	-	-	2.68 (SD 0.12)	2.72 (SD 0.06)
IPPC BREF (2003) birds/m <sup>2</sup>	18 – 24	18 – 24	18 – 24	18 - 24



The average performance figures are summarised (Table 3.5) and demonstrate an improved performance in 2004 compared to all years.

**Table 3.5: Average Performance figures for case study site (2000 – 2004)**

	All Years	2004
Crop cycles analysed (number)	30	6
FCR	1.92 (SD 0.07)	1.83 (SD 0.06)
Average weight (kg)	2.68 (SD 0.12)	2.72 (SD 0.06)
Feed (kg/bird/cycle)	4.91 (SD 0.33)	4.87 (SD 0.15)
EPEF	288 (SD 24)	319 (SD 21)
Weight (kg/m <sup>2</sup> /yr)	-	33.13

Table 3.6 demonstrates the change in nominal and actual bird place over the five years of the study. Between Year 1 and Year 5 there was a steady reduction in the number of birds placed.

**Table 3.6: Nominal vs. Actual Bird places (2000 – 2004)**

	Nominal bird places	Actual bird places
Year 1	120 000	117 780
Year 2	120 000	121 670
Year 3	120 000	117 000
Year 4	115 000	114 640
Year 5	115 000	113 020

The energy usage on the case study site in the years 2000 – 2004 has been determined (Table 3.7). The data shows that the energy usage has varied per bird over the five year period. There has been a major variance in gas usage and analysis of management practices identified that reductions in 2002 and 2003 could have been due to a change in the temperature profile. The temperature profile used an initial brooding temperature which was 2°C lower, and the rate of reduction of the temperature was altered depending on breed of bird, age of breeder hen and chick behaviour. The initial brooding temperature was raised again in 2004 in order to improve the conformity of seven day weights. (Brooding is the term given to the first seven days of the chick's life and the specific management procedures undertaken during that timeframe). The variation in electricity usage was assessed over four crops in 2002 and 2004 (Table 3.8) and demonstrated the impact of summer ventilation on increasing electricity usage. The figures of the case study site are well within the published figures provided by Defra (2004) for 2000 - 2003, but higher for 2004. The impact of external temperature on electricity usage in 2002 and 2004 has not been assessed. The variance in energy costs between summer and winter crops has been discussed in section 4.2. The water consumed by the birds was analysed over two time periods in 2002 and 2004 and compared to published water consumption figures (Tables 3.9 and 3.10).

**Table 3.7: Figures from case study unit comparing energy efficiency (2000 – 2004).**

Year	2000	2001	2002	2003	2004
Total Space (m <sup>2</sup> )	6022	6022	6022	6022	6022
Total Birds per year	706635	730009	702007	687814	678126
Birds/m <sup>2</sup>	19.6	20.2	19.4	19.0	18.7
Electricity (kWh/yr)	186579	195288	206474	194766	217806
Electricity (kWh/bird)	0.26	0.27	0.29	0.28	0.32
Electricity (kWh/1000 birds)	260	270	290	280	320
Gas (kWh/yr)	1319404	1321340	972589	1140290	1345512
Gas (kWh/bird)	1.84	1.81	1.39	1.66	1.98
Gas (kWh/1000 bird)	1840	1810	1390	1660	1980
Total Energy (kWh)	1505983	1516628	1179063	1335056	1563318
Total Weight (kg)	1758102	1933713	1783517	1792519	1754071
Average Weight of slaughtered bird (kg)	2.63	2.78	2.63	2.70	2.70
Total (kWh/bird place)	12.6	12.6	9.8	11.6	13.6
Total (kWh/1000 birds)	2100	2080	1680	1940	2300
Total (kWh/bird)	2.10	2.08	1.68	1.94	2.30
Total (kWh/bird/day)	0.04	0.04	0.03	0.04	0.04
Total (kWh/kg)	0.86	0.78	0.66	0.74	0.89
Total (kWh/m <sup>2</sup> )	250	252	196	222	260

**Table 3.8: Electricity usage on case study site for two benchmark years.**

Crop start/end date	Jul 02 – Sep 02	Sep 02 – Nov 02	Dec 02 – Jan 03	Feb 03 – Mar 03	Annual 2002	Defra (2004)
Usage (kWh/1000 birds)	365	195	220	248	260	250 - 300
Crop start/end date	Aug 04 – Oct 04	Oct 04 - Dec 04	Dec 04 – Feb 05	Feb 05 – Apr 05	Annual 2004	Defra (2004)
Usage (kWh/1000 birds)	354	297	280	272	321	250 - 300

The Defra benchmarking figures would appear to be a factor of ten lower than the other published figures and the case study site. This data too complies with “IPPC BREF”. The water utilised in cleaning has also been analysed on the case study site (Table 3.11) and meets IPPC BREF.

**Table 3.9: Benchmarking data for drinking water consumption**

	Defra (2004)	IPPC BREF (2003)	AUS (2000)
Water consumption (L/head per day/1000)	15 –30		180 - 320
Water consumption (L/head per cycle) 42 days	0.63 – 1.26	4.5 – 11	7.6 – 13.4
Water consumption (L/head per cycle) 52 days	0.78 – 1.56	4.5 - 11	9.4 - 16.6
Annual water consumption (L/bird place per year)	3.8 – 9.4	40 - 70	44 - 100

The average total mortality was analysed for the case study site between 2000 and 2004 (Table 3.12) and compared to the total mortality published figure (Defra, 2004) which is three times higher than the average figure for the case study site.

**Table 3.10: Drinking water consumption on case study site for two benchmark years.**

Crop start/end date	Jul 02 – Sep 02	Sep 02 – Nov 02	Dec 02 – Jan 03	Feb 03 – Mar 03	Annual 2002	IPPC BREF (2003)
Usage (kWh/ 1000 birds)	7.7	7.3	7.4	7.4	7.6	4.5 - 11
Crop start/end date	Aug 04 – Oct 04	Oct 04 - Dec 04	Dec 04 – Feb 05	Feb 05 – Apr 05	Annual 2004	IPPC BREF (2003)
Usage (kWh/ 1000 birds)	8.4	7.9	8.0	7.9	8.1	4.5 - 11

**Table 3.11: Benchmarking water use for terminal hygiene for case study site**

	IPPC BREF (2003)	Case Study Site 2002	Case Study Site 2004
Water use m <sup>3</sup> per m <sup>2</sup> per cycle	0.002 – 0.020	0.005 – 0.010	0.005 – 0.008
Cycles per year	6	6	6
Water use m <sup>3</sup> per m <sup>2</sup> per year	0.012 – 0.120	0.030 – 0.06	0.030 – 0.032

**Table 3.12: Case study site mortalities (2000 – 2004)**

Parameter	Case Study Site 2000 - 2004	Case Study Site 2004	Defra (2004)
Crop cycles analysed (number)	30	6	
Mean mortality (%)	3.31 (SD 1.13)	3.10 (SD 0.95)	10.00

The case study site complies with the published literature discussed in section 4.2.1. The figures obtained from the analysis of performance at the case study site during Study B in conjunction with published figures identified during the literature review stage have been used as baseline indicators for Study C. Study C involves the analysis of performance on twelve commercial broiler sites to determine the appropriateness of the QA model to a commercial situation.

### 3.5 Research Model

The objective of the research model measurement is to determine the extent to which the broiler sites assessed, currently operate in compliance with the proposed QA model and to develop benchmarking data for each KPI. The model has been tested in the field in order to determine whether it can:

- Deliver legislative compliance;
- Deliver production standards that are sustainable in the current industry price structure;
- Quantify business performance;
- Enable organisations to develop internal mechanisms for driving continuous improvement to meet key financial and quality objectives;
- Provide a management tool to aid business development; and

- Deliver transparency of standards so that consumers can make a reasoned judgment between the range of food items available when purchasing poultry meat products.

The research model has been developed with the following terminology:

<b>Baseline Requirement:</b>	Compliance with EU Legislation
<b>Higher Requirement:</b>	Compliance with EU Legislation and higher stakeholder/market driven standards.
<b>Animal Welfare:</b>	Extrinsic Standard
<b>Product Quality:</b>	Intrinsic Standard
<b>Environmental Protection:</b>	Extrinsic Standard
<b>Food Safety Standard:</b>	Food safety attribute
<b>Business Performance:</b>	Key performance Indicators that can drive business performance

The research model has been developed in two parts: the pre-requisite programme (Appendix 3) and the QA model (Appendix 4). The pre-requisite programme is implemented in conjunction with the QA model, and identifies the protocols and procedures that are the basis of good agricultural practice (GAP) in poultry meat production. The benchmarking method used was competitive benchmarking (paper nine). The development of the methodology for study C is detailed in section 3.6.

### 3.6. Design of Study C

#### 3.6.1 Introduction

The research has measured a range of indicators which can be divided into the following sub-groups:

- Traditional performance indicators:
- Traditional cost driven indicators;
- Intra-business performance indicators; and
- Additional novel QA model indicators developed within this study (Table 3.13).

These performance indicators have been previously discussed in the literature review (see Manning *et al.*, 2006c and Manning *et al.*, 2007a and paper nine). As there were constraints on the resources available for the research, the performance indicators which have been studied are highlighted using shaded cells in Table 3.13. The other indicators and their interaction are worthy of research in future studies.

**Table 3.13: Analysis of QA model indicators**

<b>Traditional performance indicators</b>	<b>Traditional cost driven indicators</b>	<b>Traditional intra-crop performance indicators</b>	<b>Additional QA model indicators</b>
Total mortality (%)	Financial returns per bird,	Daily mortality (%)	Total water consumed (L/bird/cycle) and (L/m <sup>2</sup> )
7 day mortality (%)	Financial returns per kg live weight	Daily leg culls (%)	Total water used for terminal hygiene (m <sup>3</sup> /m <sup>2</sup> )
Total leg culls (%)	Financial returns per m <sup>2</sup> .	Weekly weight gain (g)	Electricity usage (kWh/bird) and (KWh/kg liveweight)
Feed Conversion Rate (FCR)	Financial returns m <sup>2</sup> /week	Growth (%)	Gas usage (kWh/bird) and (KWh/kg liveweight)
European Production Efficiency Factor (EPEF)		Coefficient of variation (CV)	Total energy usage (kWh/bird) and (KWh/kg liveweight)
Average bird weight (kg)		Crop fill (%)	Feed usage (kg/bird) : water consumption (L/bird) ratio
Birdplace efficiency (kg/m <sup>2</sup> /week)		Daily water consumption (L/1000 birds)	Water conversion rate (L/kg liveweight)
Veterinary medicine usage (kg/1000 birds)		Daily minimum (min) /maximum (max) temperature (°C)	Water conversion rate to feed conversion rate ratio
Feed usage (kg/bird)		Ventilation rate (m <sup>3</sup> /hr/kg liveweight)	Water linear regression factor
Crop length (weeks)		Air humidity (%)	Feed linear regression factor
Bird residence period/bird age (days or weeks)		Pathogen testing (microbiological counts)	
Fallow period (days)		Internal house air quality (NH <sub>3</sub> , CO <sub>2</sub> , CO or O <sub>2</sub> ) (ppm or %)	
Hock burn (%) / Breast blisters (%) / Pododermatitis		Lighting Pattern (hours of dark and pattern of light)	
Dead on Arrivals (DOA) (%)		Light intensity (lux)	
Rejects (%)		Differential between internal and external temperature (°C)	
		Water potability (microbiological counts)	

Traditional performance indicators can be described as those indicators which are currently used in the poultry meat industry for inter-organisational on inter-crop comparative benchmarking of primary producers (paper nine). Traditional cost driven indicators are those indicators which historically have been used for both inter-organisational and intra-organisational analysis of financial performance for example, financial returns in pence per metre squared of floor area per week. Financial performance indicators have been used for inter-organisational comparative analysis benchmarking in the work undertaken by Sheppard and Edge (2006) which is discussed in Chapter 4. The advantages and disadvantages of the various benchmarking indicators which have been used to measure performance have been assessed as part of this study and are detailed in Tables 3.14, 3.15 and 3.16.

**Table 3.14: Advantages and disadvantages of using the traditional performance indicators analysed in the research study**

Performance Indicator	Advantages	Disadvantages
Total mortality (%)	<ul style="list-style-type: none"> <li>(a) Readily measurable;</li> <li>(b) An indicator of animal welfare and health status;</li> <li>(c) Recognised industry standard; and</li> <li>(d) An indicator of site environmental performance (resource management).</li> </ul>	<ul style="list-style-type: none"> <li>(a) Historic measure which cannot be reversed i.e. birds are already dead;</li> <li>(b) Medication use can skew indicator i.e. cannot compare production systems with prophylactic usage of medication and systems where therapeutic use of medication is acceptable practice; and</li> <li>(c) Crude measure which will not identify underlying sub-clinical issues which may affect bird health, growth or performance but not lead to mortality</li> </ul>
7 day mortality (%)	<ul style="list-style-type: none"> <li>(a) Readily measurable;</li> <li>(b) An indicator of chick welfare and health status;</li> <li>(c) Recognised industry standard; and</li> <li>(d) An indicator of hatchery and brooding standards;</li> </ul>	<ul style="list-style-type: none"> <li>(a) Historic measure which cannot be reversed;</li> <li>(b) Medication use can skew indicator i.e. cannot compare production systems with prophylactic usage of medication and systems where therapeutic use of medication is acceptable practice; and</li> <li>(c) Crude measure which will not identify underlying sub-clinical issues which may affect bird health, growth or performance but not lead to mortality.</li> </ul>
Leg culls (%)	<ul style="list-style-type: none"> <li>(a) Readily measurable;</li> <li>(b) Indicator of leg health status and bird welfare;</li> <li>(c) Can be used to account for any potential impact on FCR performance; and</li> <li>(d) Environmental performance indicator</li> </ul>	<ul style="list-style-type: none"> <li>(a) Historic measure which cannot be reversed; and</li> <li>(b) Crude measure which should be used in conjunction with gait scoring which will denote the degree of leg problems at an earlier stage than when culling is deemed necessary.</li> </ul>
Average weight (kg)	<ul style="list-style-type: none"> <li>(a) Routinely measured to monitor performance;</li> <li>(b) Effective measure but requires an element of resource (time/ equipment/ calibration of equipment) and the knowledge to effect change where required;</li> <li>(c) Is an indicator of bird health and may indicate sub-clinical issues which have not resulted in mortality; and</li> <li>(d) Gives an indication of feed quality/ suitability</li> </ul>	<ul style="list-style-type: none"> <li>(a) Average bird weight will drive financial performance such as kg/m<sup>2</sup>/week. However, it will not give an indication of weight consistency across the flock. This can create potentially create conflict between performance targets where growers are paid for yield (kg liveweight) but the processor requires a specific bird weight and uniformity across a crop; and</li> <li>(b) Average weight results at the end of the crop cycle will define yield but will not reflect performance on individual depletion dates, if thinned, or issues with either the pullet or cockerel performance which could be diluted within a single arithmetic mean.</li> </ul>
Birdplace efficiency (kg/m <sup>2</sup> /week)	<ul style="list-style-type: none"> <li>(a) Measure of bird performance and site efficiency; and</li> <li>(b) Relates to income as paid per kg in pence/m<sup>2</sup>/week to unit costs in pence/m<sup>2</sup>/week</li> </ul>	<ul style="list-style-type: none"> <li>(a) Historic measurement; and</li> <li>(b) Influenced by placement density of birds and cannot be used to compare different production systems unless related to a financial margin which will identify the cost of the inputs for a given output.</li> </ul>
Feed usage (kg/bird)	<ul style="list-style-type: none"> <li>(a) Identifies biggest cost of production.</li> </ul>	<ul style="list-style-type: none"> <li>(a) If measured at the end of the crop is largely historic analysis.</li> </ul>
Medicine usage (kg/ 1000 birds)	<ul style="list-style-type: none"> <li>(a) Identifies the amount of medication used.</li> </ul>	<ul style="list-style-type: none"> <li>(a) If measured at the end of the crop is largely historic analysis.</li> </ul>
Crop length/ Fallow period (days)/ Bird age (days)	<ul style="list-style-type: none"> <li>(a) Measure of bird performance; and</li> <li>(b) Fallow period is an indicator of financial performance.</li> </ul>	<ul style="list-style-type: none"> <li>(a) Often pre-determined by the processor.</li> </ul>

**Table 3.14: Advantages and disadvantages of using the traditional performance indicators analysed in the research study (cont.)**

Performance Indicator	Advantages	Disadvantages
FCR/EPEF	<ul style="list-style-type: none"> <li>(a) Can quantify performance;</li> <li>(b) Feed is the biggest cost so important to analyse efficiency of conversion; and</li> <li>(c) Can be measured during the crop - requires resource (time/ equipment) and the knowledge to effect change.</li> </ul>	<ul style="list-style-type: none"> <li>(a) Historic if produced at the end of the cycle and cannot influence change in that cycle;</li> <li>(b) Need to be able to measure bird weight and feed usage accurately during the crop to determine ongoing FCR; and</li> <li>(c) EPEF is a more complex factor that can only be measured at the end of the crop and is thus historic and cannot effect change within the crop cycle.</li> </ul>
Hock burn/ Breast blisters/ Pododermatitis (%)	<ul style="list-style-type: none"> <li>(a) Indicator of bird welfare; and</li> <li>(b) Indicator of litter quality.</li> </ul>	<ul style="list-style-type: none"> <li>(a) Crude measure cannot be reversed; and</li> <li>(b) Measures impact of historic not current status of litter quality - cannot effect change during the crop.</li> </ul>
DOA (%)	<ul style="list-style-type: none"> <li>(a) Quantitative measure of bird welfare, bird quality and food safety; and</li> <li>(b) Indication of grower performance.</li> </ul>	None
Rejects (%)	<ul style="list-style-type: none"> <li>(a) Measure of bird health/ welfare, carcase quality and food safety.</li> </ul>	None

**Table 3.15: Advantages and disadvantages of using the cost driven indicators analysed in the research study**

Performance Indicator	Advantages	Disadvantages
Financial returns per bird,	<ul style="list-style-type: none"> <li>(a) Financial measure for determining financial return per bird and can be used to determine a financial margin.</li> </ul>	<ul style="list-style-type: none"> <li>(a) Historic measure cannot effect current crop performance;</li> <li>(b) Cannot compare differing production systems as stocking density may vary; and</li> <li>(c) Reducing financial costs in isolation may have welfare implications.</li> </ul>
Financial returns per kg live weight	<ul style="list-style-type: none"> <li>(a) Measure for determining financial return - can be used to undertake a financial comparison between sites and different production systems</li> </ul>	<ul style="list-style-type: none"> <li>(a) Historic measure of crop performance; and</li> <li>(b) Reducing financial costs in isolation may have welfare implications</li> </ul>
Financial returns per m <sup>2</sup> or m <sup>2</sup> /week	<ul style="list-style-type: none"> <li>(a) Measure for determining return per m<sup>2</sup> or m<sup>2</sup>/week per kg - can be used to undertake a financial comparison between sites and different production systems</li> </ul>	<ul style="list-style-type: none"> <li>(a) Historic measure which cannot affect current crop performance.</li> </ul>

**Table 3.16: Advantages and disadvantages of using the traditional intra-crop indicators analysed in the research study**

Performance Indicator	Advantages	Disadvantages
Daily mortality (%)/ Daily leg culls (%)/Daily water consumption (L/1000 birds)	(a) Continuous measure of bird welfare; and (b) Actions can be taken during the crop to influence bird welfare and performance	None
Coefficient of variation (CV)	(a) Measurement undertaken during the first week of the crop cycle to determine chick quality and brooding performance; (b) Measurements on an ongoing basis determine the conformity of the flock; and (c) Key requirement for the fresh whole bird or portion market that birds are a uniform weight;	(a) Time consuming - if weighing birds on a routine basis using manual methods welfare needs to be considered to avoid stress.
Weekly weight gain (g)/Growth (%)	(a) Continuous measure of bird welfare; and (b) Actions can be taken during the crop to influence bird welfare and performance	None
Daily min/max temp (°C)/ Ventilation rate (m <sup>3</sup> /hr/kg liveweight)/Air humidity (%)/ Internal house air quality (ppm or %)/ Lighting Pattern (hours of dark and pattern of light)/ Light intensity (lux)/ Differential between internal and external temperature (°C)	(a) Continuous management indicator throughout the crop cycle; (b) Actions can be taken during the crop to influence bird welfare and performance; and (c) Can demonstrate compliance with legislation	None
Pathogen testing (microbiological counts)	(a) Can be undertaken prior to depletion to minimise cross-contamination during processing.	None
Water potability (microbiological counts)	(a) Undertaken to determine level of source contamination and the effectiveness of water sanitation procedures.	None
Crop fill (%)	(a) Gives indication of the effectiveness of the brooding process in the first 24 hrs.	None
Total water consumed (L/bird/ cycle) and (L/m <sup>2</sup> )	(a) Indicates environmental performance of the site; (b) Indicates the requirements for the ventilation system in terms of driving litter quality and; (c) Can be used with other indicators to determine bird welfare and performance.	(a) Historic and whole site data indicates environmental performance but individual house data is needed to cross reference to bird welfare indicators; and (b) Meters must be routinely checked to ensure accuracy.
Feed usage (kg/bird) : water consumption (L/bird) ratio	(a) Measure of ongoing performance	None
Electricity, gas or Total Energy Usage (kWh/bird) and (kWh/kg liveweight)	(a) Indicates environmental performance of the site;	None
Total water used for terminal hygiene (m <sup>3</sup> /m <sup>2</sup> )	(a) Indicates environmental performance of the site;	None
Water conversion rate (L/kg liveweight)	(a) Measure of the water consumed in relation to growth;	None
Water conversion rate to feed conversion rate ratio	(a) Measure of variance between water and feed usage	None
Water linear regression factor/ Feed linear regression factor	(a) Measure which can be used to monitor observed versus expected water or feed consumption.	None



### 3.6.2 Methodology

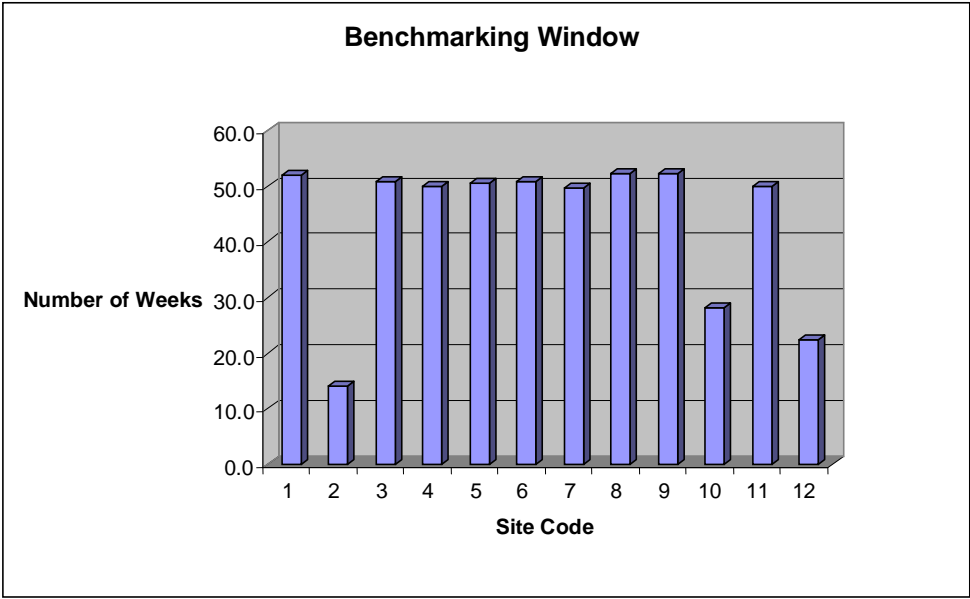
As a result of Study A, twelve sites were identified as being willing to participate in the study. These sites were growing for two different integration companies. The benchmarking window was from June 2004 until December 2005. The data was collected using a structured checklist (Appendix 5) which was sent out to the participating sites. The checklist identified site costs for 2003 and the first benchmarking data. The checklist was updated during the benchmarking process to the format described in Appendix 6. The benchmarking data was assessed from the time period of September 2004 – September 2005.

Sixty-five growing cycles (crops) were analysed on poultry sites with a range of floor area between 2676m<sup>2</sup> and 16056 m<sup>2</sup> (Average 7913 m<sup>2</sup>). The birds studied were both Ross 308 and Cobb 500 birds, but predominantly the Ross breed. Neither the breed of bird nor the age of the laying breeder hen were assessed as a factors within this study. This could be a potential limitation of the research, but the decision firstly reduced the number of individual variables assessed, and secondly the contract poultry grower does not have any input into the chicks they receive. Poultry growers must take appropriate bird management activities to ensure bird remain healthy and grow irrespective of the breed. Although integrators may provide different feed specifications for different breeds in current industry comparative cost analysis benchmarking this factor is not taken into consideration. Financial data such as rent paid, capital/loan repayments and building or equipment depreciation has not been considered within the scope of this study, rather data has been used from the Sheppard and Edge (2006) study. The sites were working to differing programmes:

1. A 52 day programme (excluding fallow period) with sexed birds in two pens with a thinning stage at 38 days when the pullets are depleted;
2. An as-hatched programme when the birds are depleted aged 39 – 42 days; and
3. Sites which were working to both programmes within the 12 month benchmarking window.

10.6 million birds were involved in the study and the range of average crop length (including fallow period) for the sites was 7.00 – 8.74 weeks with a median of 8.29 weeks. Figure 3.2 shows

the number of weeks that each site was involved in the benchmarking study with nine of the twelve sites being involved for the full length of the benchmarking process. Building design, types of ventilation and heating system has not been taken into consideration during the analysis of the results. The houses were all built to a standard industry design and used liquid propane gas as the heating source. Any other design differences were considered to be outside the scope of the study and again are not factors considered in current UK industry comparative benchmarking analysis.



**Figure 3.2: Duration of benchmarking window by site**

The source of site water including quality and mineral content excepting where this shows a strong influence on bird performance has not been investigated but is worthy of further study (see 4.3.1). External air temperature was not measured on the sites during this study but winter and summer energy usage has been compared (see section 4.4). This could be a potential limitation to the research, but this variable as well as water suitability has been considered outside the scope of the study when comparing site performance. All of the variables previously described do have an impact on individual crop or site performance and are worthy of further study or inclusion in a future refinement of the model.

The QA model has drawn together a series of intra-crop performance indicators which can be used to measure food safety, animal welfare, product quality, environmental protection, and business performance (Appendix 4). The advantages of these traditional and novel intra-crop performance indicators are that they can be evaluated in order to provide information on the current crop

including for example, daily water consumption or daily mortality. One of the aims of this research study has been to add to the existing portfolio of indicators which are available to poultry growers to be able to influence and modify performance during the crop cycle. The QA model has essentially been developed in order that:

- It can be easily communicated to poultry growers;
- It utilises as many traditional indicators as possible which are familiar to the growers;
- Performance can be readily identified; and
- The statistical analysis involved in the QA model can be undertaken by growers using a standard computer spreadsheet.

### **3.6.3 Data collection**

The data collection has been developed based on the following factors:

- The primary data has been provided by commercial poultry sites rather than under the controlled conditions of poultry research sites;
- There are a number of known and also possibly unknown variables in commercial poultry production. In this commercial situation it is not possible to develop a scientific experiment where only one variable is changed at a time in order to determine its independent influence. Therefore the primary data has been used in the main to define the strength of relationships rather than to demonstrate statistically significant results; and
- This study aims to either identify trends or relationships which are worthy of further study within a rigorous experimental framework or to compare the results where possible with secondary data such as published research in order to determine the validity of the primary data produced in this study.

### **3.6.4 Statistical analysis**

Descriptive statistics have been used; namely the arithmetic mean, the median, range and IQR which is a measure of spread for quantitative variables and has been defined as the 3rd quartile minus the 1st quartile. Commercial “best practice” has been considered depending on the variable

to be performance above the 3<sup>rd</sup> quartile or below the 1<sup>st</sup> quartile. Variation and dispersion of data has been analysed using standard deviation,  $r$ , the correlation coefficient, and  $r^2$  the coefficient of determination. The statistical approach used has also been chosen so that there can be direct comparison with the work by Dawkins *et al.*, (2004) and other authors, where applicable. The methods used included:

- Constructing a scattergraph to illustrate the relationship between two variables and then determining a line of best fit. The disadvantage to this method is that it does not, when used on its own, give an indication of the strength of the relationship;
- Linear regression where there is an apparent positive relationship between two variables, determining the intercept and the slope;
- Determining the correlation coefficient ( $r$ ), coefficient of determination ( $r^2$ ) and the value of  $r$  (i.e. positive or negative). The Pearson product-moment correlation coefficient has been used. This coefficient is only valid if the data is from a normally distributed population. It has been taken into consideration that correlation is only a measure of linear relationships, and that nonsense correlations are possible and a significant result does not imply any underlying reason for the association nor that one variable is the cause of another variable;
- Student t-test and standard error of the means (sem) to compare two sample populations; and
- Chi-squared test to determine differences between observed and expected data.

### **3.7 Conclusion**

This chapter has identified the preparative research that has been undertaken in developing the QA model. The results of study C are now discussed in detail in Chapter 4. As previously discussed the results have been compared where relevant to research data defined in published literature which has been referenced to the appropriate authors.

## CHAPTER 4 – ANALYSIS AND DISCUSSION OF THE RESEARCH MODEL DATA

### 4.1 Introduction

The key results of the benchmarking study have been analysed in this chapter. Supporting graphical analysis of the data can be found in Appendix 7 and is cross-referenced throughout the chapter. The analysis has been undertaken in order to demonstrate;

- (a) The results of the study and whether they comply with published literature if this is available;
- (b) Whether the performance indicators can differentiate between good, average and poor performers (using interquartile range (IQR) and/or histograms); and
- (c) Whether two or more indicators can be used together to gain a further understanding of performance on the site and/or during the crop cycle.

### 4.2 Traditional performance indicators

The mortality figures which were measured in this study were total mortality, seven day mortality and leg culls.

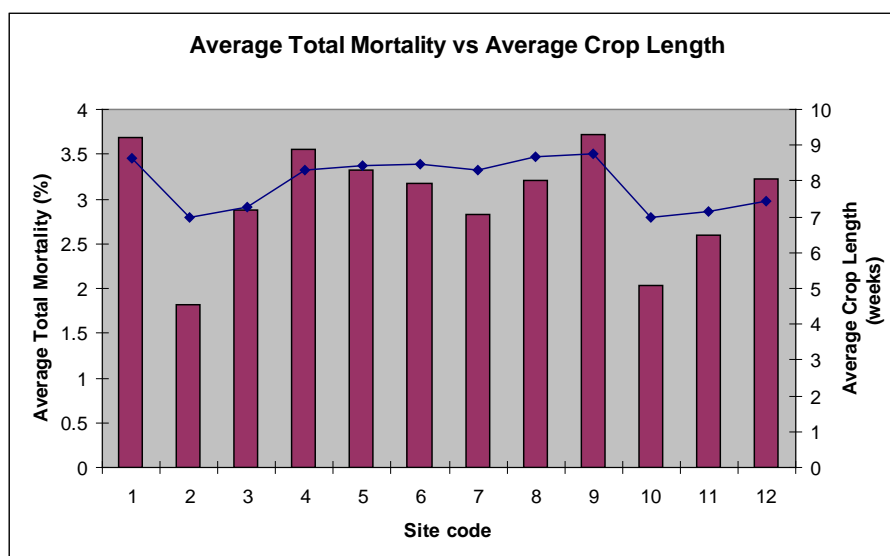
#### 4.2.1 Total mortality

The mean total mortality for all sites ( $n = 12$ ) was 3.00% (SD 0.61, IQR 2.77 - 3.38) and for all crops ( $n = 65$ ) was 3.08% (SD 0.97, IQR 2.42 – 3.67), which compared to the case study site (Table 3.12). Defra (2004) define an average mortality rate of 10%; Heier *et al.*, (2002) 4.42% at 42 days; Sheppard and Edge (2006) 4.1%; and in the study undertaken by Dawkins *et al.*, (2004) the mean total mortality was 4.1% with a range of 1.4 – 14.7. The proposed EU Broiler Welfare Directive puts forward a formula for determining average mortality of 1% plus 0.06% multiplied by the slaughter age of the flock in days. This would correspond to a mortality figure of 3.52% at 42 days and 4.12% at 52 days (or 3.70% for a composite sexed system depleted at 38 and 52 days). The data produced as a result of this study for average site total mortality complies with the proposed Directive and 95.4% of all crop cycles ( $n=65$ ) are also compliant. Sites 2 and 10 had the lowest mortality rate compared to the IQR. Sites 1, 4 and 9 had the worst performance and were above the IQR, (Table 4.1).

**Table 4.1: Site performance with regard to bird performance for traditional indicators**

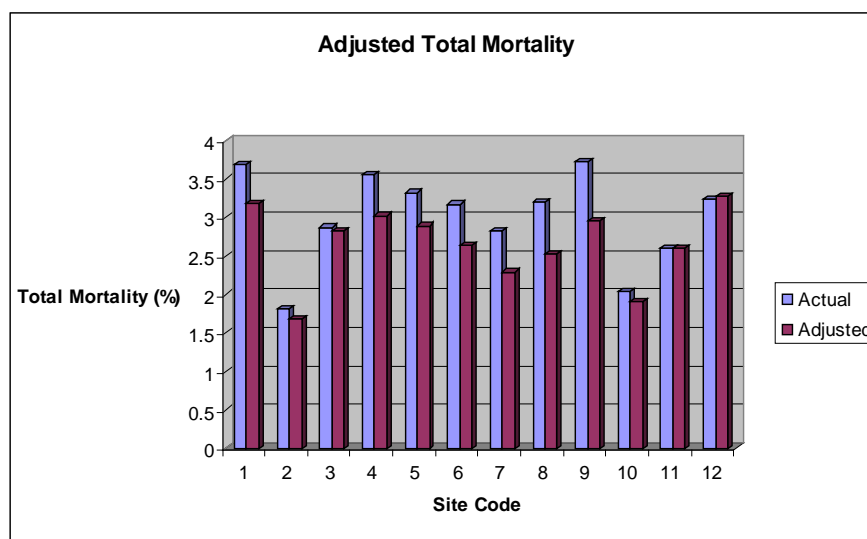
Parameter	Worst performing sites		Best performing site	
	Group 1	Group 2	Group 1	Group 2
Total mortality (%)	1, 4, 9	-	-	2, 10
7 day mortality (%)	4, 8	11	5, 6,	10, 12
Leg culls (%)	1, 6, 9	-	4	2, 10
FCR	4, 9,		-	10,12
EPEF	-	2, 3, 11	1, 5, 8	-
Average weight (kg)	4, 7	-	6	12
BPE (kg/m <sup>2</sup> /wk)	8, 9	12	-	2, 10, 11
Feed usage (kg/bird)	-	-	-	10
Crop length (weeks)	1, 8, 9,	3,12	-	
Fallow period (days)	5,	12	-	

The proposed Broiler Welfare Directive determines that total mortality is related to crop length i.e. the longer the crop length the higher the mortality. The mean total mortality and mean crop length by site has been analysed (Figure 4.1). Heier *et al.*, (2002) in their research on mortality in Norwegian broiler flocks concluded that the average weekly cumulative mortality was 1.54% during the 1st week and 0.48% per week during the rest of the crop. This factor has been used to adjust the data from the twelve sites for variable bird residency period and fallow period (length of time that site was empty).



**Figure 4.1: Average Total Mortality vs. Average Crop Length**

The mean total mortality figures were adjusted to a bird residency period of 6 weeks (42 days). Bird residency as termed in this study is the length of time (in days) that birds were resident in the house and not the average age of the birds as the latter is affected by thinning of pullets (px) at a younger age than cockerels (cx). The graph demonstrates the influence of crop length on total mortality (Figure 4.2).



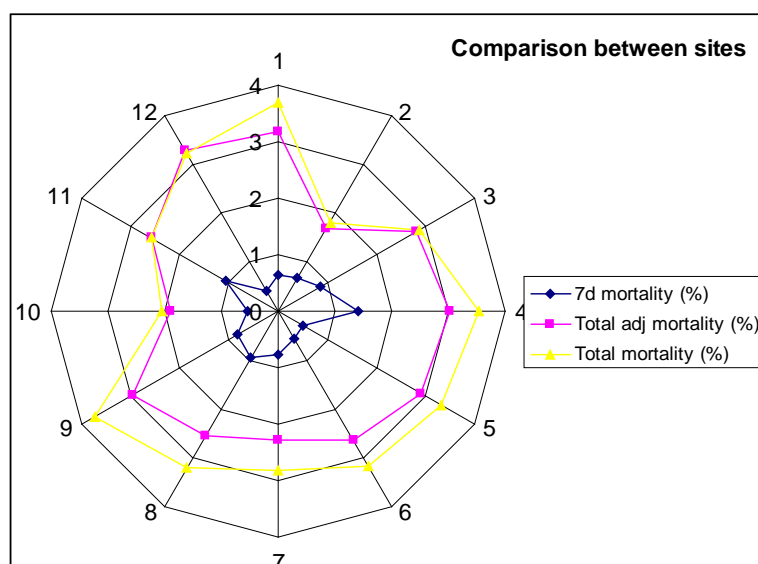
**Figure 4.2: Actual vs. Adjusted Total Mortality**

The adjusted mortality figures also indicated that sites 2, 7 and 10 had the best performance with sites 1, 4 and 12 demonstrating the worst performance with Site 9 just on the top of the third quartile (Table 4.1). The average mortality has been compared to average residence period and the results suggest that the longer the residency period, the higher the total mortality as would be expected. Statistical analysis was undertaken using sem (same method as the Dawkins *et al.*, 2004 study). This demonstrated that there was a statistically significant difference between actual and adjusted data ( $p < 0.05$ ). Therefore in order to objectively compare total mortality either on different sites or different growing programmes with a variable fallow or bird residence period an adjustment should be made for the variance.

#### 4.2.2 Seven day mortality

Individual site performance was analysed against figures identified in the literature review. The mean seven day mortality for all sites ( $n = 12$ ) was 0.76% (SD 0.27, IQR 0.57 – 0.87) and the mean seven day mortality across all crops ( $n = 56$ ) was 0.78% (SD 0.38, IQR 0.54 – 0.88). Site 4 had the highest seven day mortality (Appendix 7: Figure 7.2), but it is still below the published figure of 1.54% (Heier *et al.*, 2002) and 1.42% (Proposed EU Broiler Welfare Directive). The best performing sites were sites 5, 6, 10, and 12 (below the IQR); the worst performing sites were 4, 8 and 11. It is important to consider the impact of any therapeutic medication that may be administered to the chicks which would influence the level of early mortality. This data has remained confidential and therefore cannot be reported in this study but will have an impact on

the QA model and should be considered during comparative horizontal private benchmarking. Comparison of seven day, total mortality and adjusted total mortality (Figure 4.3) show no correlation. The  $r$  value for seven day: total mortality is 0.18 and seven day: adjusted total mortality is 0.08.



**Figure 4.3: Average total mortality, adjusted average mortality and 7 day mortality by site**

However, seven day mortality as well as seven day bird weight is a valuable measure of chick quality on arrival and also in determining the effectiveness of brooding management (see 4.5.9 where this theme is developed further).

### 4.2.3 Leg cull mortality

The mean leg culls for all sites ( $n = 12$ ) was 0.69% (SD 0.41, IQR 0.44 – 1.03). The mean leg cull mortality across all crops ( $n = 52$ ) was 1.05% (SD 0.58, IQR 0.65 – 1.10). This compared with the results obtained by Dawkins *et al.*, (2004) who identified a range of leg culls from 0 – 2.4% (mean of 0.6%). The sites with the best performance were sites 2, 4 and 10 and the worst were sites 1, 6 and 9 all with results above the third quartile and all three sites were in Group 1 i.e. the bird residency period was over 42 days. Dawkins *et al.*, (2004) undertook research on sites with a bird residency period of 6 weeks (39-42 days). The data from the benchmarking group has been analysed for Group 1 (crops with a residency period of over 42 days) and Group 2 (crops with a residency period of 42 days or less) see Appendix 7: Figure 7.3. There was a statistically significant difference (using sem) between the two sets of data (Group 1 mean = 1.05, SD= 0.58; Group 2 mean = 0.36, SD= 0.26,  $p < 0.05$ ). This result demonstrates that the influence of bird



residence period needs to be considered when monitoring leg culls during horizontal benchmarking of either production sites or different production systems. Group 2 demonstrated an improved performance compared to the results reported Dawkins *et al.*, (2004).

The correlation between leg culls and seven day mortality was weak ( $r = -0.21$ ,  $r^2 = 0.04$ ). The use of therapeutic medication which is outside the scope of reporting could potentially skew the results for leg culls as previously explained for 7 day mortality. The correlation coefficient between leg culls (%) and average weight (kg) was  $r = 0.57$ ,  $r^2 = 0.32$  which demonstrated weak correlation. The correlation coefficient between leg culls (%) and total mortality (%) was  $r = 0.82$ ,  $r^2 = 0.67$  which established a stronger correlation. This result is expected in that the higher the level of leg culls the higher the total mortality would be. Site performance with regard to the three mortality indicators has been compared in Table 4.1. Sites 2 and 10 are the best performing site on all indicators with site 10 performing well with regard to all three indicators. Sites 1, 4 and 9 were the worst performing sites with regard to mortality in two out of three indicators respectively.

#### **4.2.4 FCR**

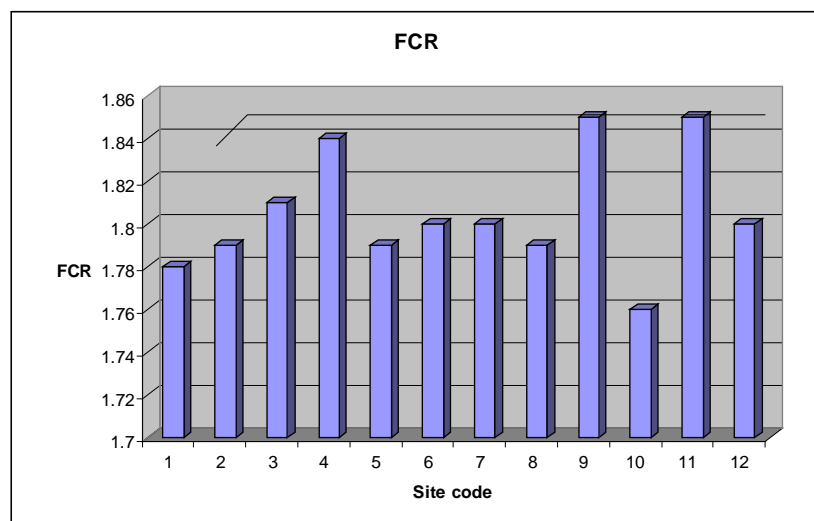
Measures of broiler performance include FCR and EPEF which are in fact measures of feed efficiency. Feed efficiency of broilers is affected by bird age, sex, health and environmental temperature although the major factor is usually dietary energy concentration (Leeson, 2002). The mean FCR for all sites ( $n = 12$ ) was 1.81 (SD 0.03, IQR = 1.79 – 1.82) and for all crops ( $n = 63$ ) was 1.81 (SD 0.06, IQR = 1.76 – 1.85) see Figure 4.4. The data from the benchmarking group has been analysed for Group 1 (mean crop length = 8.74, mean FCR = 1.81, SD = 0.06, IQR = 1.76 – 1.85) and Group 2 (mean crop length = 7.13, mean FCR = 1.80, SD = 0.06, IQR = 1.75 – 1.85). Ross (2006) define both FCR and average weight benchmarking figures for the Ross 308 (Table 4.2). The results indicate that although the groups had very similar results neither were meeting the predicted FCR for bird age. The variation in average FCR between groups was calculated as 0.01. This was much smaller than expected and could have been due to differences in feed specification or growing standards between the groups. The average weight for the Group 2 birds was lower than expected this could therefore explain the poorer FCR. The IQR suggested

variation between growing sites and this was also probably due to bird age on depletion and for all sites (n = 12) the FCR IQR = 1.79 – 1.82 compared to 1.76 – 1.85 for all crops (n = 65). Therefore IQR rather than average FCR may be the more appropriate measure of group performance.

**Table 4.2: Ross 308 performance Figures for FCR and Average Weight**

	Ross 308 42 day as hatched	Ross 308 38 day female	Ross 308 52 day male	Composite 52 day
FCR	1.72	1.68	1.83	1.76
Results	1.76 – 1.85			1.76 – 1.85
Average Weight (kg)	2.47	1.97	3.57	2.77
Results	2.11 – 2.17			2.68 – 2.79

The sites with the worst performance were 4, and 9 (Table 4.1); sites with the best performance were 10 and 12 (Figure 6).



**Figure 4.4: Average FCR per site**

The impact of dietary energy concentration between the different groups feed rations is considered outside the scope of this study as this remains confidential to the integrators.

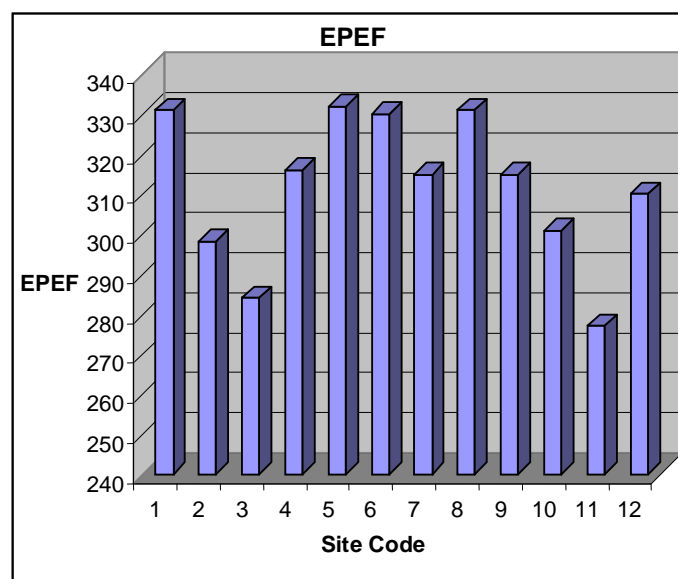
#### 4.2.5 EPEF

EPEF is determined by the formula below:

$$\text{EPEF} = \frac{\text{Liveability} \times \text{Liveweight in Kg} \times 100}{\text{Age in Days} \times \text{FCR}}$$

The mean EPEF for all sites (n = 12) was 312 (SD 19, IQR 300 -330) and the mean EPEF for all crops (n = 65) was 312 (SD 25, IQR 295 - 328). The data from the benchmarking group has been

evaluated for Group 1 (mean EPEF = 326, SD = 20, IQR 312 - 341) and Group 2 (mean EPEF = 293, SD = 18, IQR 278 - 305). The mean EPEF per site (Figure 4.5) shows a variance between sites. The sites with the best performance were sites 1, 5 and 8 (Table 4.1) and the worst sites 2, 3 and 11. There is a weak negative correlation between EPEF and FCR i.e. the lower the FCR the higher the EPEF ( $r = -0.56$   $r^2 = 0.31$ ) see Appendix 7 Figure 7.6 which compares FCR and EPEF by site.



**Figure 4.5: Average EPEF per site**

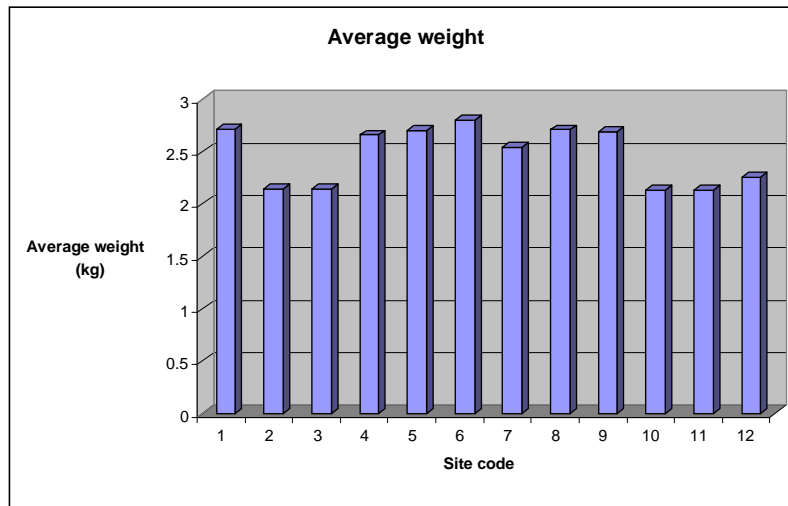
#### 4.2.6 Average weight

The mean bird weight for all sites ( $n = 12$ ) was 2.47 kg (SD 0.28, IQR 2.15 – 2.70) and the mean bird weight for all crops ( $n = 64$ ) was 2.50 kg (SD 0.30, IQR 2.16 – 2.72). The data from the benchmarking group has been examined for Group 1 (mean bird weight = 2.74 kg, SD = 0.10, IQR = 2.68 – 2.79) and Group 2 (mean bird weight = 2.18 kg, SD = 0.04, IQR = 2.11 – 2.17). Ross Breeders (2006) define average weight benchmarking figures for the Ross 308 (Table 4.2). The results indicate that neither group was meeting the predicted average weight nor the FCR for bird age. The data also show the average weight per site (Figure 4.6) and the difference in weight profiles between the two groups (Appendix 7: Figure 7.8). There was a statistically significant difference (using sem) between the two sets of data demonstrating that the groups were growing to distinct bird depletion weights ( $p < 0.05$ ). Using the IQR:

- Group 2 the best site performance was site 12, all other sites were in the IQR;

- Group 1 the best site performance was site 6, the worst were sites 4 and 7.

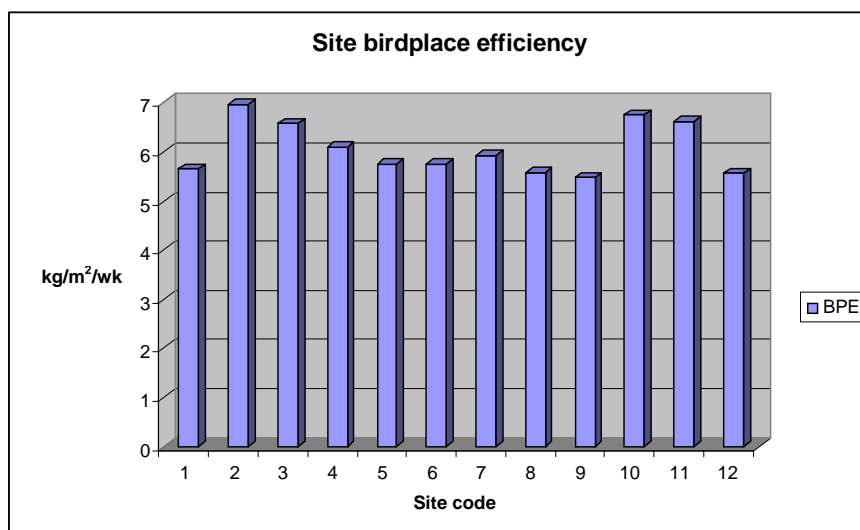
The impact of dietary energy concentration between the different groups feed rations as previously discussed is outside the scope of this study.



**Figure 4.6: Average weight by site**

#### 4.2.7 Birdplace efficiency

The mean bird place efficiency (BPE) for all sites i.e. the production level of the growing site from the start of one crop to the start of the next crop i.e. including fallow period ( $n = 12$ ) was 6.06 kg/m<sup>2</sup>/wk (SD 0.53, IQR 5.64 – 6.59 kg/m<sup>2</sup>/wk) and for all crops ( $n = 65$ ) was 6.02 kg/m<sup>2</sup>/wk (SD 0.59, IQR 5.53 – 6.59 kg/m<sup>2</sup>/wk). The data from the benchmarking group has been assessed for Group 1 (mean BPE = 5.60 kg/m<sup>2</sup>/wk, SD = 0.23, IQR 5.46 – 5.66 kg/m<sup>2</sup>/wk) and Group 2 (mean BPE = 6.59 kg/m<sup>2</sup>/wk, SD = 0.41, IQR 6.38 – 6.83). The range of BPE between sites is shown in (Figure 4.7) and between groups (Appendix 7: Figure 7.8). There was a strong negative correlation coefficient between BPE and average weight by site ( $r = -0.80$ ,  $r^2 = 0.64$ ) and a weaker negative correlation by crop ( $r = -0.74$ ,  $r^2 = 0.55$ ). There was no correlation within the group when group 1 data and group 2 data were analysed independently. There was a strong negative correlation between BPE and total mortality by site ( $r = -0.86$ ,  $r^2 = 0.74$ ) but weak correlation by crop ( $r = -0.38$ ,  $r^2 = 0.15$ ). There was no correlation within the group when group 1 and group 2 data were analysed independently.



**Figure 4.7: Birdplace efficiency by site**

This negative correlation was in part due to the impact of the variance in stocking density between the two groups. This led to the sites with the higher total mortality still having a greater BPE because the initial placement density and the resultant depletion density were higher. There was a strong positive correlation between birdplace efficiency and placement density by site ( $r = 0.96$ ,  $r^2 = 0.92$ ) and a weaker but still strong positive correlation by crop ( $r = 0.85$ ,  $r^2 = 0.73$ ) which are both significant at  $p = 0.05$ . There was no intra-group correlation when group 1 and group 2 data were analysed independently. There was a strong positive correlation between BPE and depletion density by site ( $r = 0.96$ ,  $r^2 = 0.93$ ) and a weaker correlation by crop ( $r = 0.88$ ,  $r^2 = 0.77$ ) which are both significant at  $p = 0.05$ . Again there was no intra-crop correlation.

Therefore it could be suggested that the birdplace efficiency is driven by placement and depletion stocking density (birds/m<sup>2</sup>), rather than average weight when comparing different production systems. There was, as would be expected, a greater correlation with depletion density. IQR was used to determine site performance for bird place efficiency:

- Group 2 - the best site performance was site 2, but sites 10 and 11 were above the third quartile: the worst was site 12;
- Group 1 – all sites were within the IQR excepting sites 8 and 9 who were below the first quartile;

#### 4.2.8 Feed usage

The mean feed usage for all sites ( $n = 12$ ) was 4.38 kg/bird (SD 0.52, IQR = 3.87 – 4.81) with the mean feed usage for all crops ( $n = 64$ ) being 4.45 kg/bird (SD 0.59, IQR = 3.83 – 4.93). The data from the benchmarking group has been analysed for Group 1 (mean feed usage = 4.90 kg/bird, SD = 0.22, IQR = 4.74 – 5.03) and Group 2 (mean feed usage = 3.85 kg/bird, SD = 0.30, IQR 3.65 – 3.91). There was a strong correlation coefficient between feed usage (kg/bird) and average weight (kg) by site ( $r = 0.99$ ,  $r^2 = 0.98$ ) and by crop ( $r = 0.97$ ,  $r^2 = 0.94$ ). Using linear regression the line of best fit suggests by site that  $y = 1.84x - 0.17$  where  $x$  = average weight (kg) and  $y$  = feed usage (kg/bird). This feed linear regression (FLR) equation compares with the FCR results by site of 1.81. Using linear regression the line of best fit suggests by crop that  $y = 1.90x - 0.33$  where  $x$  = average weight (kg) and  $y$  = feed usage (kg/bird).

The variation in actual and expected feed usage by crop was calculated using both formulae to determine which would be the most appropriate to use in the QA model. The results have been plotted (Figure 4.8) and suggest that with FLR sites 3, 9 and 11 are the poorest performers with sites 6, 10 and 12 as the best performers. The variance per site (FLR) was analysed and compared to FCR variance (Figure 4.9).

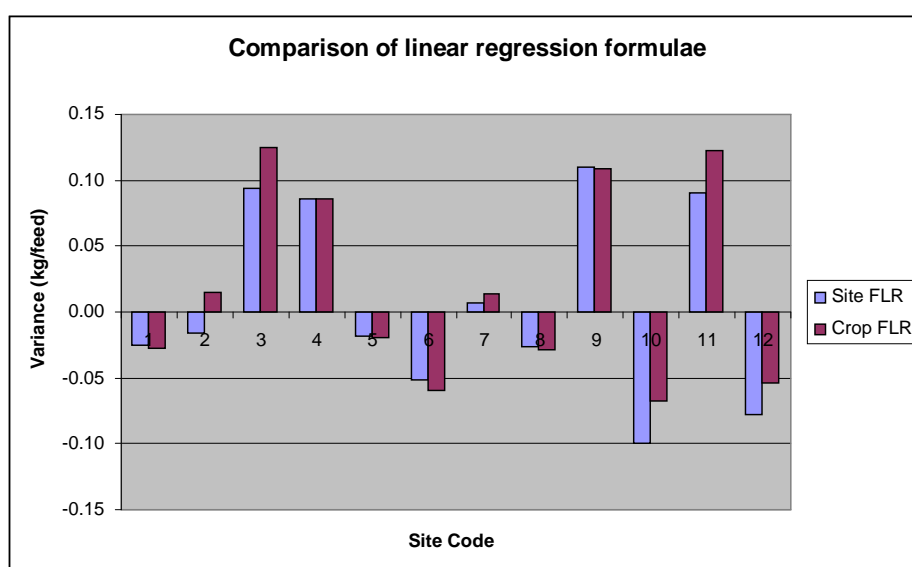
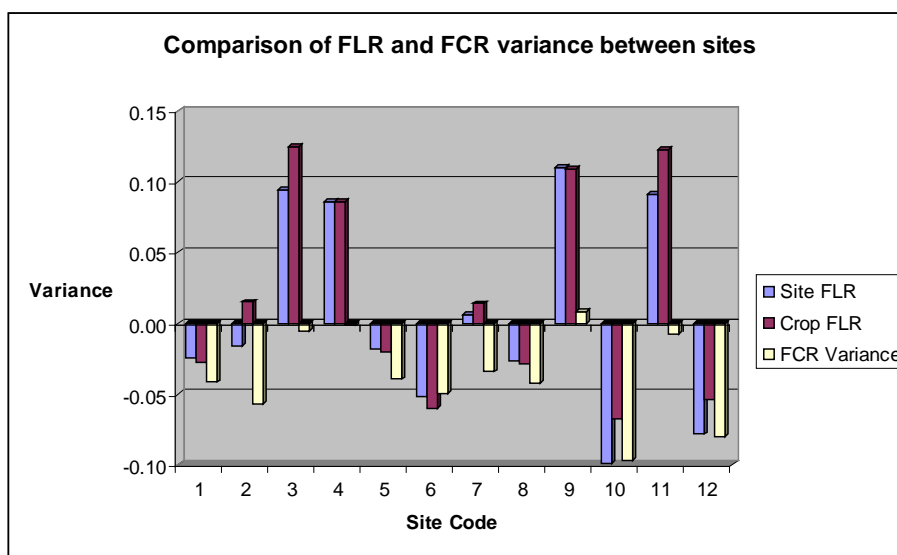


Figure 4.8: Comparison of two linear regression formulae



**Figure 4.9: Variance in FCR and variance in FLR (linear regression feed usage: average weight) by site**

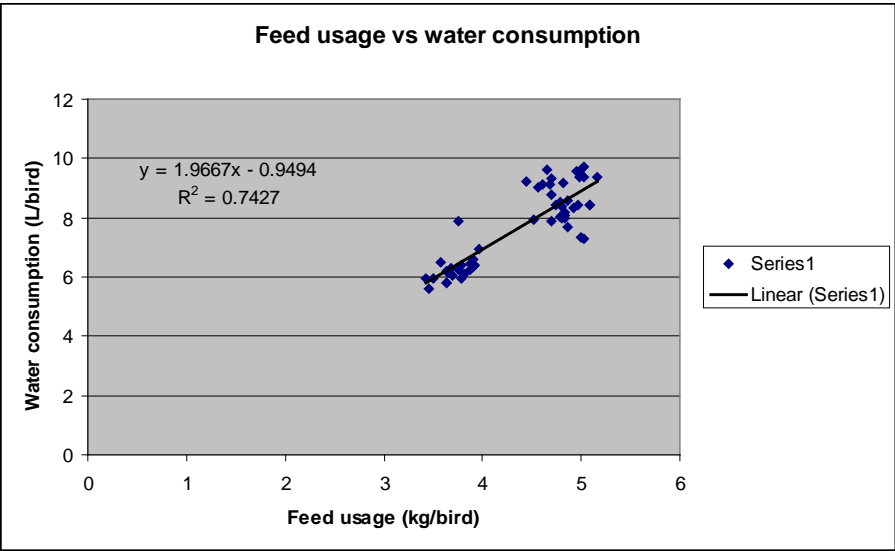
The comparison is shown in Table 4.3. Although sites 9, 10, and 12 are identified by both parameters using FLR also identifies sites 3, 4 and 6 as outside the IQR. Further research needs to be undertaken with a larger data set to determine whether the FLR formula is a useful tool within the QA model.

**Table 4.3: Summary of feed usage variance analysis**

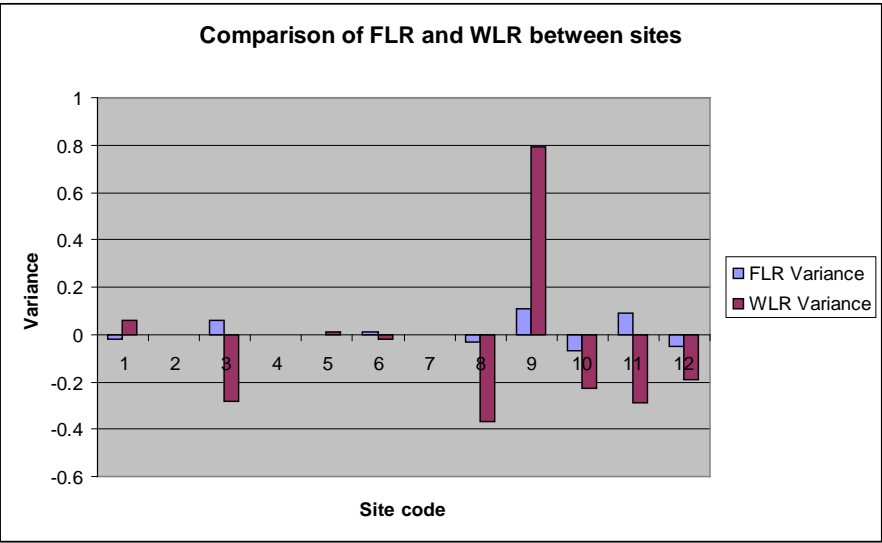
Parameter	Worst performing sites (Top quartile)	Best performing site (Lowest quartile)
FCR	4, 9	10, 12
FLR	3, 9, 11	6, 10, 12

There was a strong positive correlation between feed usage (kg/bird) and water consumption (L/bird) by site was  $r = 0.86$ ,  $r^2 = 0.74$ , but no intra-crop correlation. There was also a strong positive correlation between average weight (kg/bird) and water consumption (L/bird), where  $r = 0.87$ ,  $r^2 = 0.75$  (Figure 4.10). At confidence level  $p = 0.05$  these results are deemed statistically significant. From Figure 4.10, using linear regression the line of best fit suggests that  $y = 1.97x - 0.95$  where  $x$  = feed usage and  $y$  = water consumption. This water linear regression (WLR) formula forms the basis for a calculation to determine expected water consumption on the basis of the feed quantity consumed. The variance from expected results for FLR and WLR is shown in Figure 4.11. Sites 2, 4, and 7 were not compared because the small amount of data (two crop comparison) skewed the figures. The graph shows that site 9 has a much higher than expected water consumption in (L/bird). Chi-squared analysis suggested that there was no statistical

difference between observed and expected WLR (at  $p = 0.05$ ) for the sites studied. Nevertheless, this calculation proved an important indicator in determining those sites that had a higher than expected water consumption in (L/bird) which could then be followed up by the site manager.



**Figure 4.10: Feed usage and its relationship to water consumption by crop**



**Figure 4.11: Variance in FLR and WLR by site**

Previous research in the literature has assessed the ratio between feed and water consumption and the research suggested that there was a relationship between the two values (Georgia, 2001) and Lott *et al.*, (2003). Ross (2006) suggested that drinker design would affect water: feed ratio namely nipple drinkers without cups 1.6:1; nipple drinkers with cups 1.7:1 and bell drinkers 1.8:1. Cornelison *et al.*, (2005) evaluated eight different drinker systems and concluded that proper management of drinker systems was essential for maximising broiler performance. The research indicated that the static flow rates (mL/min) varied significantly between the different systems

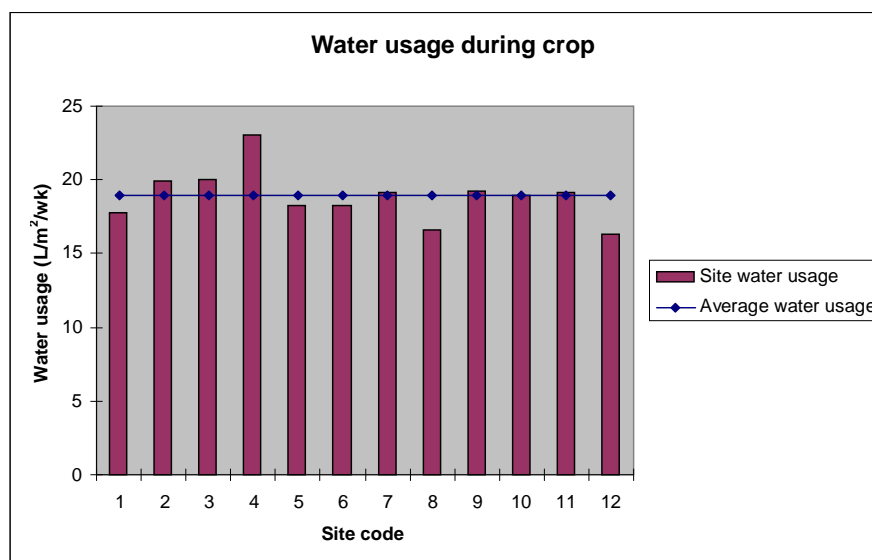


tested and that litter moisture under the drinkers was on average 35.7% (SD= 7.9, IQR 28.7 – 41.5). Lacey (2002) reported a ratio water consumption: feed consumption ratio of 1.80 for a 2.3 kg liveweight broiler. The literature also proposed that there is a difference between the summer and the winter ratio of water: feed ratio (L: kg feed) stating a ratio of 1.5 in the winter and 1.77 in the summer (Georgia, 2001). It is suggested (Singleton, 2004) that water consumption increases by 6% for every 1°C rise in temperature from that at 20°C where it approximates to 1.8 – 2.0 times feed quantity. The same author proposes that feed intake is reduced by 1.23% for every 1°C rise in temperature and by 5% for every 1°C rise between 32 – 38 °C. Reduced feed intake is the main cause of poor performance in hot weather. This study has identified that the ratio varies between summer and winter production and between production systems (Table 4.4).

**Table 4.4: Summary of water consumption: feed usage ratio for each group (L: kg feed)**

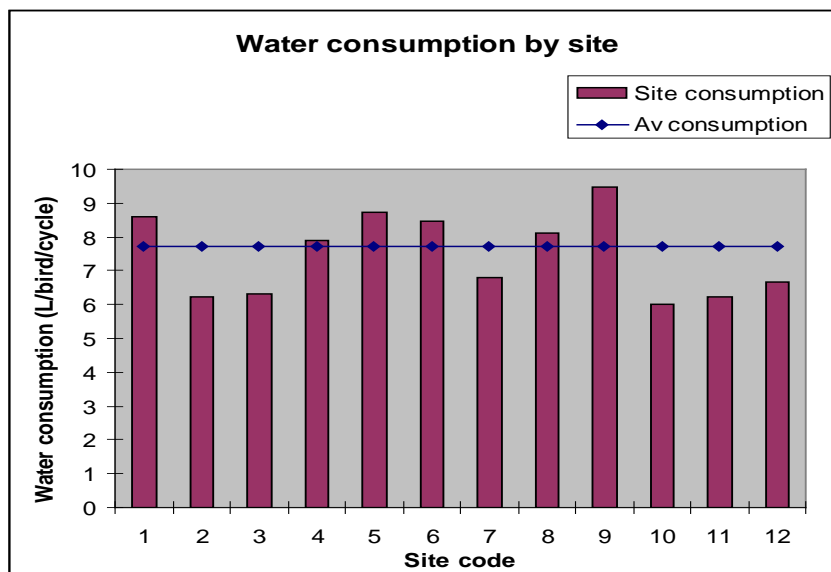
Crop Cycle	Group 1 (Average weight 2.74 kg)	Group 2 (Average weight 2.18 kg)
1 (Sept/Oct)	1.75	-
2 (Nov/Dec)	1.62	1.65
3 (Jan/Feb)	1.72	1.66
4 (Mar/Apr)	1.77	1.64
5 (May/Jun)	1.93	1.70
6 (Jul/Aug)	1.93	1.74

The ratio for Group 2 was 1.65 in the winter and 1.72 in the summer. The ratio for the larger birds (Group 1) showed much greater variance across the crop cycles and within crop cycles. The ratio was much greater in the summer crop with a range of 1.67 – 2.07.



**Figure 4.12: Water usage per site (L/m<sup>2</sup>/wk)**

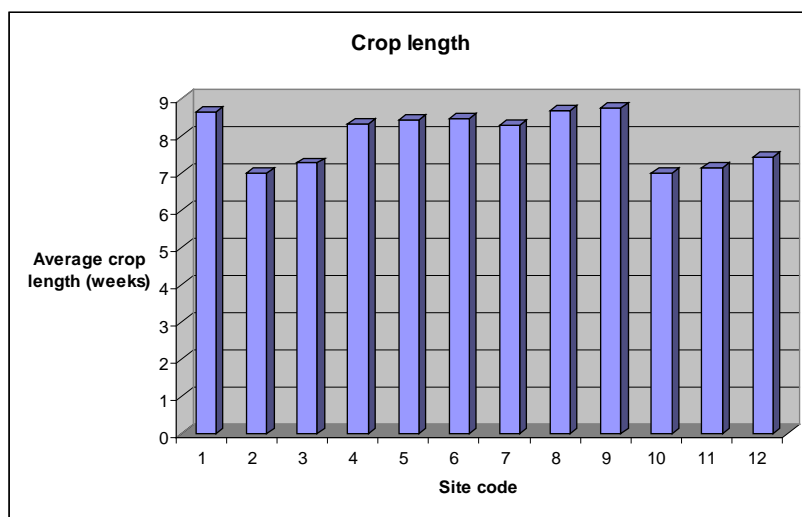
Water usage per site has been analysed in terms of L/m<sup>2</sup>/wk (Figure 4.12) and water consumption in terms of L/bird/cycle (Figure 4.13). The high level of water consumption on site 4 (Figure 4.12) has been identified as being due to the high mineral content of the bore-hole water and this factor is also worthy of investigation on site 9 (Figure 4.13). Further research should be undertaken to determine if the ratio can be used as a bird welfare and/or feed suitability indicator.



**Figure 4.13: Water usage per site (L/bird/cycle)**

#### 4.2.9 Crop length

The mean crop length for all sites ( $n = 12$ ) was 7.95 weeks (SD 0.71, IQR 7.24 – 8.51 and for all crops ( $n = 64$ ) was 8.04 weeks (SD 0.86, IQR 7.00 – 8.86) see Figure 4.14. The data for Group 1 (mean crop length = 8.74 weeks, SD = 0.32, IQR = 8.57 – 9.00) and Group 2 (mean crop length = 7.13 weeks, SD = 0.26, IQR = 7.00 – 7.15). The variance in crop length will impact on BPE as the longer crop length could have given rise to a longer fallow period i.e. the BPE reduces when the houses are left empty. There was a strong negative correlation between birdplace efficiency (kg/m<sup>2</sup>/wk) and crop length  $r = -0.84$ ,  $r^2 = 0.71$  which is deemed significant at  $p = 0.05$ . The difference in average fallow period between groups was 1.36 days. Sites 1, 3, 8, 9 and 12 were outside the 3<sup>rd</sup> quartile for crop length for their respective group.



**Figure 4.14: Average crop length by site**

#### **4.2.10 Fallow period**

The mean fallow period for all sites ( $n = 12$ ) was 8.44 days (SD 1.6, IQR 7.86 – 9.13) and for all crops ( $n = 64$ ) was 8.56 days (SD 2.59, IQR 6.75 – 10.00). The data from the benchmarking group has been analysed for Group 1 mean fallow period = 9.14 days (SD 1.92, IQR 8.00 – 10.00) and Group 2 mean fallow period = 7.78 days (SD 3.17, IQR 5.00 – 10.00). Sites 5 and 12 had the longest fallow period which was outside the IQR for both groups.

#### **4.2.11 Conclusion**

The results reported to date are collated in Table 4.5 by site and by crop cycle. The traditional indicators demonstrate a strong difference in terms of mean values and IQR between group 1 and group 2. Statistical analysis of variance was undertaken using sem because the number of samples ( $n$ ) was too high for a student  $t$  test. The results show that other than for seven day mortality and FCR there is a statistically significant difference between the two production systems. Therefore, this study would propose the two production systems should not be considered as equivalent when undertaking comparative performance or financial benchmarking. The analysis of the worst and best performers for the traditional indicators (Table 4.1) demonstrate that the best performing site in most categories is site 10 ( $n = 6$ ) and the worst performing was site 9 ( $n = 5$ ).

**Table 4.5: Summary of results for traditional performance indicators**

Indicator	Number (N)	Mean (x)	Standard Deviation	IQR
Total mortality by site (%)	12	3.00	0.61	2.77 – 3.38
Total mortality by crop (%)	65	3.08	0.98	2.42 – 3.67
7 day mortality by site (%)	12	0.76	0.27	0.57 – 0.87
7 day mortality by crop (%)	56	0.78	0.38	0.54 – 0.88
Leg culls by site (%)	12	0.69	0.41	0.44 – 1.03
Leg culls by crop (%)	52	1.05	0.58	0.65 – 1.10
Feed Conversion Rate by site (FCR)	12	1.81	0.03	1.79 – 1.82
Feed Conversion Rate by crop (FCR)	63	1.81	0.06	1.76 – 1.85
European Production Efficiency Factor by site (EPEF)	12	312	19	300 – 330
European Production Efficiency Factor by crop (EPEF)	65	312	25	295 – 328
Average bird weight by site (kg)	12	2.47	0.28	2.15 – 2.70
Average bird weight by crop (kg)	64	2.50	0.30	2.16 – 2.72
Birdplace efficiency by site (kg/m <sup>2</sup> /week)	12	6.06	0.53	5.64 – 6.59
Birdplace efficiency by crop (kg/m <sup>2</sup> /week)	65	6.02	0.59	5.53 – 6.59
Feed usage by site (kg/bird)	12	4.38	0.52	3.87 – 4.81
Feed usage by crop (kg/bird)	64	4.45	0.59	3.83 – 4.93
Average crop length by site (weeks)	12	7.95	0.71	7.24 – 8.51
Average crop length by crop (weeks)	64	8.04	0.86	7.00 – 8.86
Fallow period by site (days)	12	8.44	1.60	7.86 – 9.13
Fallow period by crop (days)	64	8.56	2.59	6.75 – 10.00

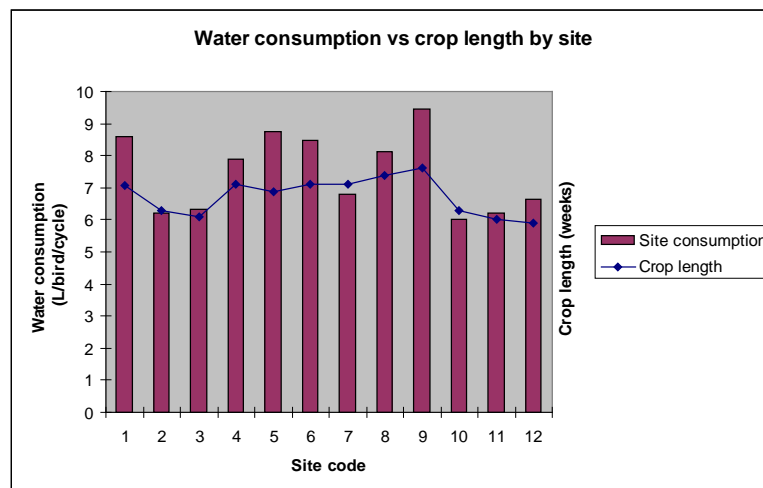
The study now analyses the results from the additional QA indicators which demonstrate the level of compliance with environmental legislation such as IPPC, but also potentially offer further information on crop cycle and bird performance.

### 4.3 Additional QA performance indicators

#### 4.3.1 Total water consumption

Water intake by birds will depend on a number of factors including breed and age, animal health and well-being, feed composition, water temperature and water quality and drinking system used (Cobb 1995, Ross 2006). Water losses could be due to leakage or the poor management of the drinkers which could cause spillage. Water pressure and type of nipple system will also influence

water availability from the system when the bird drinks (Manning *et al.*, 2007c). Due to the nature of the data, i.e. that it originates from commercial rather than research sites, neither the influence of mineral content of the drinking water nor the impact of mineral content with regard to feed composition has been analysed within this study but is worthy of further investigation. The total water consumed for all sites ( $n = 12$ ) was 7.46 L/bird/cycle (SD 1.21, IQR 6.30 - 8.50); the mean water consumption for all crops ( $n = 51$ ) was 7.70 L/bird/cycle (SD 1.31, IQR 6.36 – 8.80). The water consumption range of 5.58 – 9.62 L/bird/cycle complied with the IPPC BREF (2003) standard of 4.5 – 11 L/bird/cycle. Individual site performance was also analysed (Figures 4.13 and 4.15) and showed the variance between individual sites and also between crop lengths, the latter would have been expected as the longer the residence period the more the individual bird will drink.



**Figure 4.15: Water consumption by site compared to crop length**

The correlation between feed usage and water consumption has been previously discussed (4.2.8). The correlation coefficient between water consumption and crop length is ( $r = 0.80$ ,  $r^2 = 0.64$ ); water consumption and bird residence period ( $r = 0.73$ ,  $r^2 = 0.53$ ), and average weight ( $r = 0.92$ ,  $r^2 = 0.84$ ) all are statistically significant at  $p = 0.05$ . There is therefore a strong relationship between water consumption, crop length, feed consumption (see 4.2.8) and average weight. However, the limitation of total water consumption as an indicator for assessing bird performance and welfare is that it is historic, covers all houses on the site rather than individual houses or pens and implies that all the water that enters the house is consumed. Nevertheless, it is a powerful indicator of environmental performance and bird health and the usefulness of this

indicator is developed more fully in section 4.5.1 which studies the relationship between total and daily water consumption.

#### 4.3.2 Water used for terminal hygiene

Results from 46 crops have been analysed and the mean volume of water used for all crops was  $0.010 \text{ m}^3/\text{m}^2$  (SD 0.006, IQR 0.006 – 0.011). This complies with the IPPC BREF (2003) benchmark of 0.002 – 0.020  $\text{m}^3/\text{m}^2$ .

#### 4.3.3 Electricity Usage

Electricity usage is a factor of the ventilation rate which is affected by external temperature, internal air quality, litter quality and the stocking density of birds in terms of  $\text{kg}/\text{m}^2$ . The limitations of the study are that electricity usage varies according to season so only crop cycles that are in the same time period can be compared or annual site figures. The data suggests that the summer crops use more electricity and the winter crops use less. This is due to the increased ventilation profile in the summer in order to keep the birds cool. Only three sites provided annual figures with an average energy usage of 238 kWh/1000 birds with a range of 205 – 298 kWh/1000 birds. Defra (2004) put forward the benchmarking figure of 250 – 300 kWh/1000 birds, and all three sites were compliant with the upper limit. Figure 4.16 shows a comparison of the annual figures across the three sites.

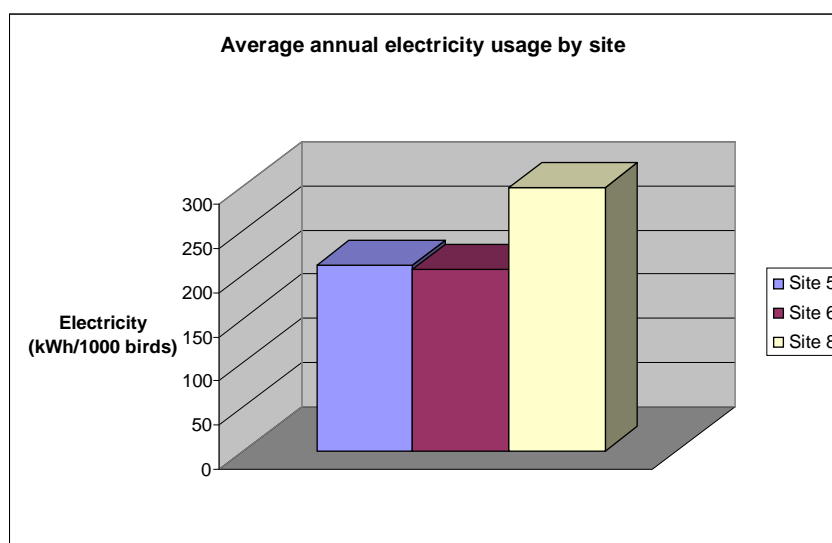
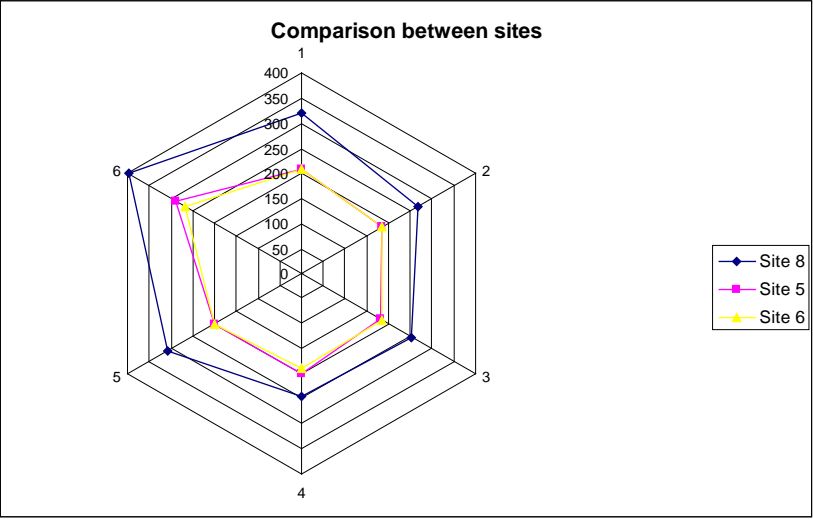


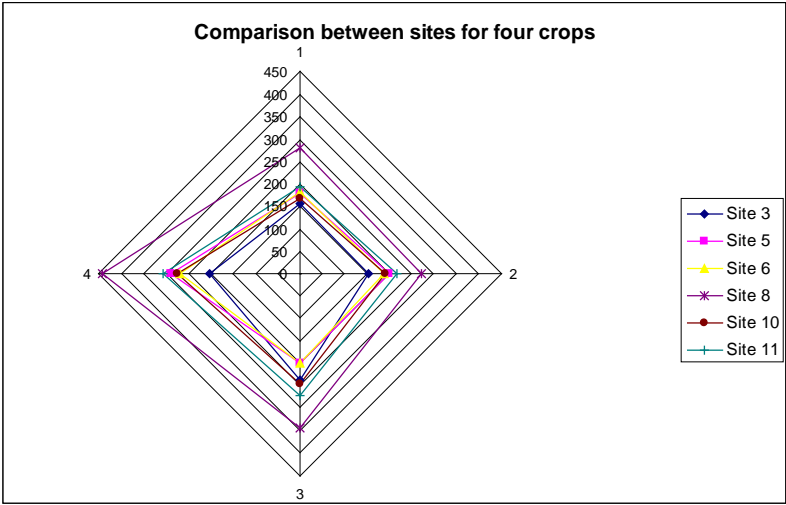
Figure 4.16: Comparison of annual electricity usage across three sites in kWh/1000 birds

This data has been analysed by crop cycle on a spider diagram (Figure 4.17). The shape of the diagram is the same for all sites again reflecting similar ventilation profiles, however, site 8 has used a much higher level of electricity usage compared to the other two sites.



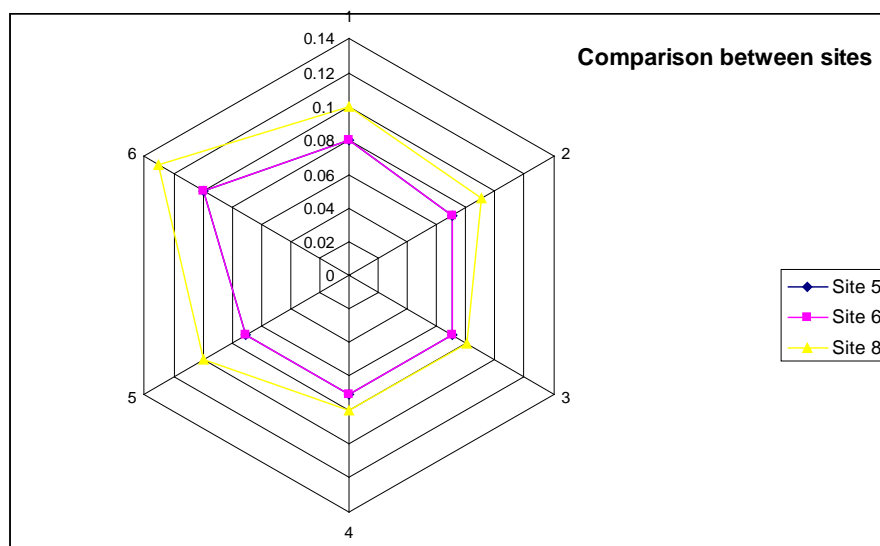
**Figure 4.17: Comparison of annual electricity usage by crop across sites in kWh/1000 birds (spider diagram)**

Six sites have been compared for four crops (average electricity usage - 235 kWh/1000 birds, IQR 213 – 258 kWh/1000 birds, Figure 4.18) and this also shows much higher electricity usage at site 8 (301 kWh/1000 birds). Sites 3 and 6 were the lowest usage sites. The two groups were compared i.e. those crop cycles 42 days and under and those over 42 days, using sem and there was no statistically significant difference for electricity usage between the two groups.



**Figure 4.18: Comparison of electricity usage for four crops across six sites in kWh/1000 birds (spider diagram)**

There was also no correlation between electricity usage and crop length, bird residence period or water usage either in kWh/1000 birds or kWh/kg liveweight. The average annual usage for three sites in terms of kWh/kg liveweight is shown in Figure 4.19. This demonstrates the identical electricity consumption of sites 5 and 6. Site 8 has the higher electricity consumption. Using kWh/kg liveweight as the indicator for the four crops on the six sites, site 5 and 6 are the best sites; 8 is now within the IQR and 11 is the worst performing site for the four crop cycles studied. There is a strong positive correlation between the two factors for measuring energy usage ( $r = 0.82$ ,  $r^2 = 0.68$ ). The last two crop cycles are in the summer when there is the greatest electricity usage (May – August). These results suggest that when undertaking electricity usage benchmarking and comparing production systems there is a differentiation in perceived site performance in terms of kWh/1000 birds (due to the variance in placement density and crop length) compared with kWh/kg liveweight. Therefore the IPPC BREF indicator kWh/1000 birds, cannot be used to compare different production systems. It is argued in this study that kWh/kg liveweight is the preferred indicator because it is more closely linked to ventilation rates. The major usage for electricity is for ventilation and the ventilation rate is directly proportional to the kg of liveweight in the poultry house. Further research needs to be undertaken to determine which parameter provides the most beneficial information.

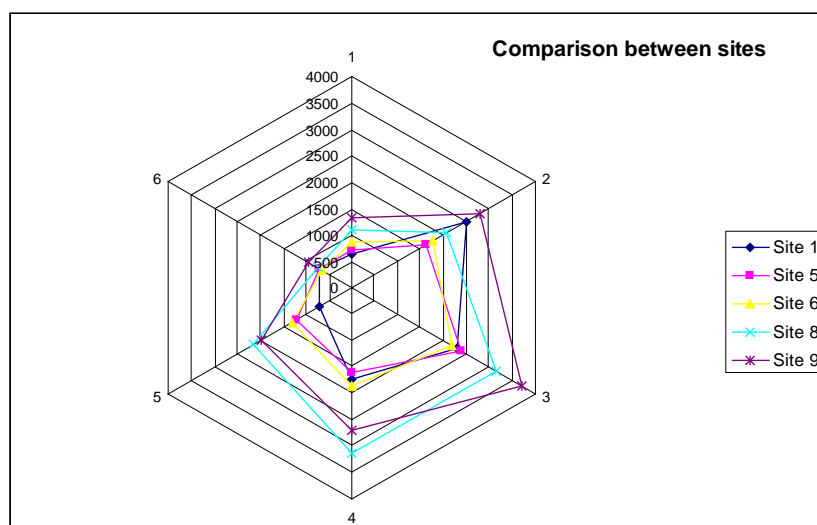


**Figure 4.19: Comparison of annual electricity usage by crop across three sites in kWh/kg liveweight (spider diagram)**



#### 4.3.4 Gas Usage

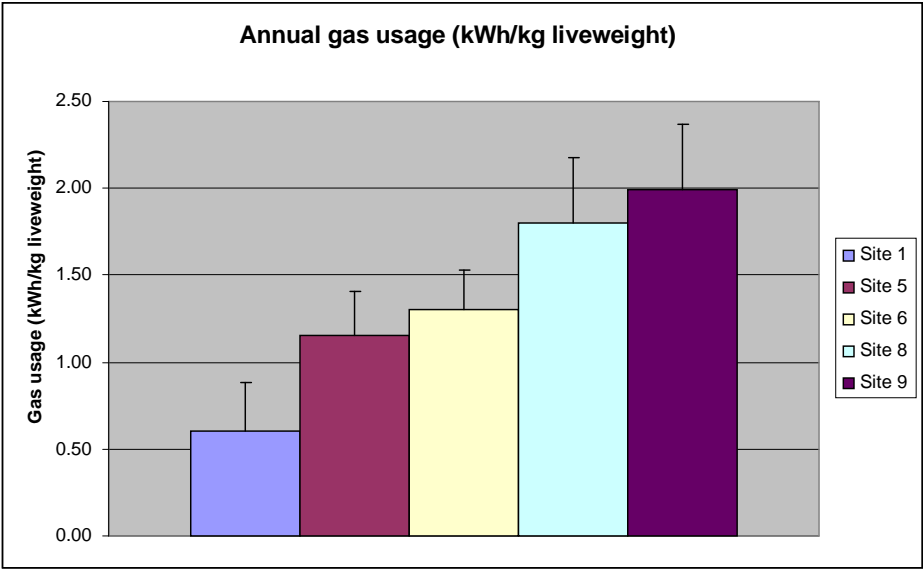
Gas usage is the inverse of electricity usage i.e. gas usage for heating is greatest in the winter when electricity is at its lowest usage and vice versa in the summer. The average annual gas usage has been analysed for the five sites that provided data (Figure 4.20). The average usage per site was 1462 kWh/1000 birds per cycle (IQR 1222 – 1763 kWh/1000 birds). Site 5 had the lowest usage with sites 1 and 6 on the first quartile. Site 9 was above the third quartile. The electricity usage provided a similar shape on the spider diagram but the gas usage shows different shapes for different sites, which may be a multi-factorial result due to variance in either bird residence period, different growing temperature profiles or the external air temperature during brooding either increasing or decreasing gas usage. The correlation coefficient between average gas usage and average bird residence period for these sites is  $r = 0.97$ ,  $r^2 = 0.94$ , which is statistically significant at  $p = 0.05$ . This would indicate that gas usage is closely related to bird residence period i.e. the longer the bird residence period the more gas is used per bird, but not necessarily per  $m^2$ .



**Figure 4.20: Comparison of annual gas usage across five sites in kWh/1000 birds (spider diagram)**

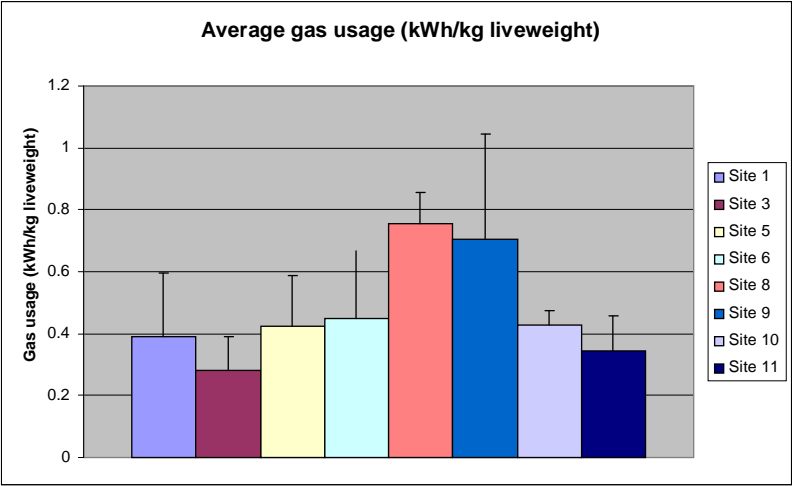
There was no correlation shown between average water consumption and average gas usage by site. The gas usage per site was also analysed for the last three crops of the benchmarking period for eight sites. The average was 1219 kWh/1000 birds with an IQR of 877 - 1411 kWh/1000 birds. Sites 3 and 11 had the lowest usage below the first quartile. Sites 8 and 9 were above the third quartile.

The average annual gas usage per site for the five sites was 1.37 kWh/kg liveweight per cycle (IQR 1.15 – 1.8 kWh/kg liveweight) see Figure 4.21.



**Figure 4.21: Comparison of average annual gas usage per crop cycle in kWh/kg liveweight**

Site 1 rather than site 5 had the lowest usage with site 5 on the first quartile. Sites 8 and 9 were above the third quartile. The gas usage per site was also analysed for the last three crops of the benchmarking period for eight sites (Figure 4.22).

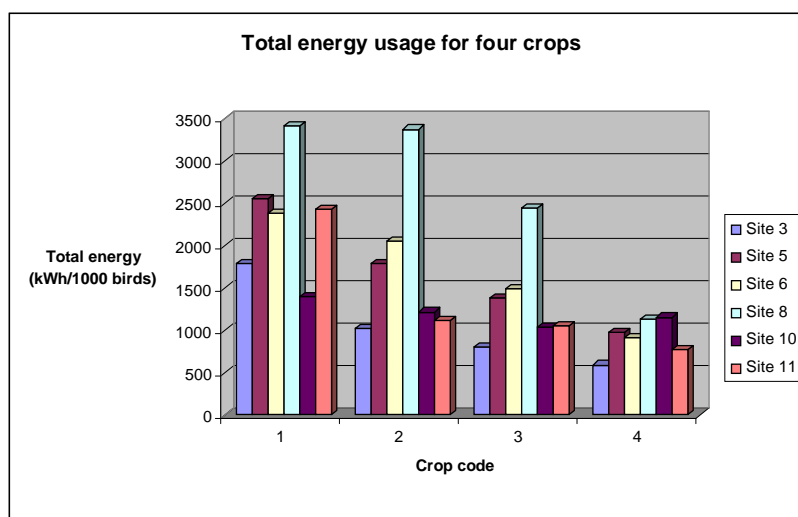


**Figure 4.22: Comparison of gas usage per crop across eight sites in kWh/1000 birds**

The average gas usage per crop cycle was 0.47 kWh/kg liveweight with an IQR of 0.39 – 0.47 kWh/kg liveweight. Sites 3 and 11 had the lowest usage below the first quartile. Sites 8 and 9 were above the third quartile as with kWh/1000 birds.

### 4.3.5 Total Energy Usage

The total energy usage has been analysed for six sites over four crops. The average usage per site was 1596 kWh/1000 birds (IQR 1237 - 1703 kWh/1000 birds). Sites 3 and 10 had the lowest energy usage with sites 6 and 8 above the third quartile (Figure 4.23).



**Figure 4.23: Comparison of total energy usage for four crops across six sites in kWh/1000 birds**

Peirson, (1999) suggested a total energy usage figure per crop of 1360 – 1930 kWh/1000 birds for a 42 day bird. The average figure in this study complies with this standard excepting site 8 which was growing to a 52 day programme which could account for the variance. There was a strong positive correlation between total energy usage (kWh/bird) and average residency period ( $r = 0.89$ ,  $r^2 = 0.79$ ) and between total energy usage (kWh/kg liveweight) and average bird residence period ( $r = 0.72$ ,  $r^2 = 0.52$ ) which are both statistically significant at  $p = 0.05$ ; but the correlation was stronger between bird residence period and energy usage per bird which would be expected. The total energy usage has been analysed for six sites over four crops in terms of kWh/kg liveweight. The average usage per site was 0.68 kWh/kg liveweight (IQR 0.53 – 0.63 kWh/kg liveweight). Sites 3 and 11 had the lowest energy usage with site 8 above the third quartile. The energy performance of all sites has been summarised (Tables 4.6 and 4.7) and demonstrates that sites 6, 8 and 9 have the highest energy usage (52 day crop cycles) in terms of per bird and per kg liveweight. The two groups were compared for the last four crop cycles using sem and there was a statistically significant difference between those crop cycles 42 days and under and those over 42 days when comparing kWh/1000 birds.

**Table 4.6: Summary of results for traditional performance indicators**

Indicator	Number (N)	Mean (x)	Standard Deviation	IQR
Total water consumption by site (L/bird/cycle)	12	7.46	1.21	6.30 – 8.50
Total water consumption by crop (L/bird/cycle)	51	7.70	1.31	6.36 – 8.80
Total water for terminal hygiene by crop (m <sup>2</sup> /m <sup>3</sup> )	46	0.01	0.006	0.006 – 0.011
Annual average electricity usage per crop by site (kWh/1000 birds)	3	238	53	205 – 298 (range)
Electricity usage per crop from Jan - Aug (kWh/1000 birds)	24	235	39	213 - 258
Annual average gas usage per crop by site (kWh/1000 birds)	5	1462	352	1222 - 1763
Annual average gas usage per crop by site (kWh/kg liveweight)	5	1.37	0.55	1.15 – 1.18
Gas usage per crop from Mar - Aug (kWh/1000 birds)	24	1219	476	877 - 1411
Gas usage per crop from Mar - Aug (kWh/kg liveweight)	24	0.47	0.16	0.39 – 0.47
Total energy usage per crop Jan - Aug (kWh/1000 birds)	24	1596	553	1237 - 1703
Total energy usage per crop Jan - Aug (kWh/kg liveweight)	24	0.68	0.29	0.53 – 0.63

**Table 4.7: Site performance with regard to resource usage**

Parameter	Worst performing sites		Best performing site	
	Group 1	Group 2	Group 1	Group 2
Water consumption all sites (L/bird/cycle)	1,6,9	-	2, 10,11	-
Terminal hygiene (m <sup>2</sup> /m <sup>3</sup> )	-	-	-	-
Annual electricity usage (kWh/1000 birds) (Sites 5,6,8)	-	-	-	-
Electricity usage (kWh/1000 birds) (Sites 3,5,6,8,10,11)	8 (*site 9 not assessed)	-	6	3
Electricity usage (kWh/kg liveweight) (Sites 3,5,6,8,10,11)	-	11	5,6	-
Annual Gas usage (kWh/1000 birds) (Sites 1,5,6,8,9)	9	-	1,5,6	-
Annual Gas usage (kWh/kg liveweight) (Sites 1,5,6,8,9)	8, 9	-	1	-
Gas usage (kWh/1000 birds) (Sites 1,3,5,6,8,9, 10,11)	8, 9	-	-	3,11
Gas usage (kWh/kg liveweight) (Sites 1,3,5,6,8,9, 10,11)	8, 9	-	-	3,11
Energy usage (kWh/1000 birds) (Sites 3,5,6,8,10,11 – four crop cycles)	6, 8, (*site 9 not assessed)	-	-	3,10
Energy usage (kWh/kg liveweight) (Sites 3,5,6,8,10,11 – four crop cycles)	8, (*site 9 not assessed)	-	-	3, 11

The sites that were over 42 days were using higher total energy per bird as would be expected. This research would suggest that when using this parameter different benchmarking figures should be in place for differing production systems. There was a weaker correlation between bird residence period and energy usage in kWh/kg liveweight ( $r = 0.72$ ,  $r^2 = 0.52$ ).

Energy usage (in kWh/kg liveweight) for the last four crops for the two groups was compared using sem and there was no significant difference between the two groups. Therefore it can be argued that when comparing electricity usage between production systems, this is the more appropriate indicator. During the benchmarking window although all four sites were in the same group (over 42 days) sites 8 and 9 demonstrated a much higher energy usage than sites 5 and 6. The results were communicated to the sites after they received results from the benchmarking window after the fifth crop. The year on year of gas usage over the next crop has been collated (Table 4.8). The results show that the gas usage was unchanged for sites 8 and 9, but the costs were reduced per bird and per kg liveweight for sites 5 and 6 largely driven by the increase in birdplace efficiency suggesting that stocking density will influence energy efficiency.

**Table 4.8: Comparative year on year performance with regard to energy usage**

Site Code	Gas usage 2004 (kWh/ 1000 birds)	Gas usage 2005 (kWh/ 1000 birds)	Gas usage 2004 (kWh/kg liveweight)	Gas usage 2005 (kWh/kg liveweight)	Difference (kWh/ 1000 birds)	Difference (p/bird)	Difference (p/kg)	BPE 2004	BPE 2005
5	709 (CL 9.00)	458 (CL 6.29)	0.27	0.23	- 251	- 0.58	- 0.28	5.45	5.70
6	863 (CL 9.00)	605 (CL 6.14)	0.31	0.29	- 258	- 0.59	- 0.28	5.37	5.83
8	808	828	0.40	0.32	-28	0.00	0.00	5.61	5.53
9	1325	1358	0.48	0.51	33	0.00	0.00	5.53	5.57

CL = crop length

It is therefore argued that energy usage benchmarking should be introduced into comparative benchmarking analysis in order to drive energy usage improvements and potential cost savings. It is important to consider the impact of stocking density and growing programme when determining energy efficiency; however this is not addressed with the current BREF IPPC standard.

#### 4.3.6 Conclusion

The benchmarking data discussed so far in this chapter has been historic data. This type of information can assist a grower in identifying what went right/wrong and how this affected bird health and welfare, and ultimately business performance. The performance indicators described have not demonstrated that they can assist the grower to change or modify performance during the crop cycle. This study has not only researched traditional and additional QA models indicators but also sought to analyse and further develop real-time indicators which can influence management practices during the crop cycle and these are discussed in section 4.5.

#### 4.4 Comparative financial analysis

The financial performance of retailers and processors has been previously discussed (see Chapter Two). The financial data collated during this benchmarking study has been analysed to determine whether the data obtained is comparative to the results obtained by Sheppard and Edge (2006). The limitations of the comparison are that Sheppard and Edge only studied birds that were placed in March or April 2005 and the benchmarking study looked at birds placed over a 12 month period. The figures also indicate that average output for the benchmarking study (birdplace efficiency) was 39.6 kg/m<sup>2</sup> which is just above the Assured Chicken Production (ACP) standard of 38 kg/m<sup>2</sup> (ACP, 2006). This compared with 44.4 kg/m<sup>2</sup> in the Sheppard and Edge study (59% of their correspondents stated that they would have to change their stocking density to meet the ACP target). In order to compare the data effectively, as the Sheppard and Edge study compared birds from different production systems the benchmarking data has been pooled. However, the research limitation of interpreting such pooled data has been previously shown in this study (4.2.11). The two studies are compared (Table 4.9) and show that although the number of crops examined was similar (64:67), the number of birds involved in this study was 42% higher.

**Table 4.9: Comparison of current Study with Sheppard and Edge (2006)**

	Sheppard and Edge (2006) (n=67)	Benchmarking Study (n=65)
Membership of ACP (% of flocks)	85 (74% in 2002)	100
Membership of ACP (% of birds)	92 (84% in 2002)	100
Thinning (% of flocks)	48 (38% in 2002)	57
Thinning (% of birds)	45 (29% in 2002)	42
Output (kg/m <sup>2</sup> /yr)	44.4 (45.1 in 2002)	39.6
Number of crops	67	64
Number of birds placed (millions)	7.03	10.00
Number of birds depleted (millions)	6.74	9.61
Liveability (%)	95.9	96.9
Average weight (kg)	2.44	2.41
Average residence period (days)	47	47.2

Liveability and overall average weight figures were similar as was residence period. The breakdown of costs in the Sheppard and Edge study (Figure 4.24) shows that the highest costs are feed and chicks. The benchmarking study did not consider the impact of rent (as the sites were all privately owned) nor did it consider capital repayments/depreciation but focused primarily on variable costs which were easier to quantify and compare. The financial data obtained from this study has been compared with the financial data from the aforementioned authors in Table 4.10.

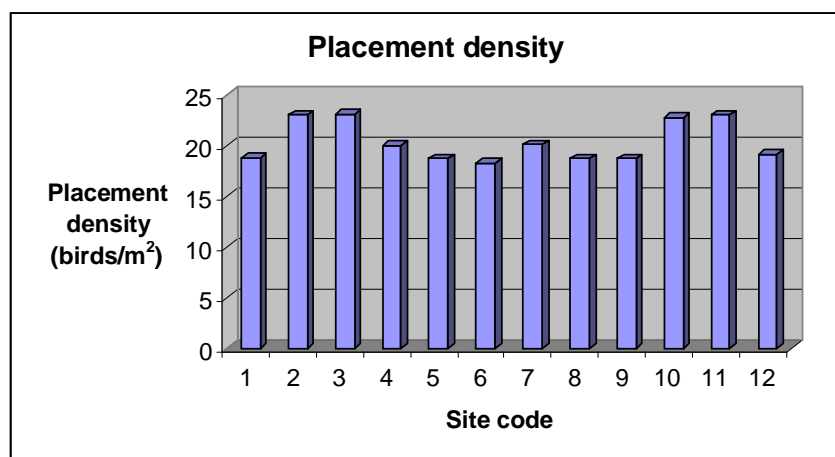
**Figure 4.24: Breakdown of poultry costs in p/bird (Source: Sheppard and Edge 2006)**

**Table 4.10: Comparison of financial data between current study and Sheppard and Edge (2006)**

Performance indicator	Sheppard and Edge (2006) (n=67)	Sheppard and Edge (2006) (n=34)	Benchmarking Study (n=65 unless otherwise stated)
Mortality (%)	4.1	3.6	3.08
Weight of birds sold (kg)	2.44	2.53	2.50
Return per kg sold (pence)	48.8	49.1	Sheppard and Edge Standard
Average residence period (days)	47 (n=46)	44	47.2
Value of bird (pence)	119	<b>123.9 stated by S&amp;E their data actually suggests 124.2</b>	122.8
Costs (pence/bird or p/bird)		122	121 (see Table 4.11)
<b>Margin (p/bird)</b>		<b>1.9 stated by S&amp;E their data actually suggests 2.2</b>	<b>1.8</b>

Although the chick and feed costs per bird were comparable between the two studies, the health and welfare costs (vaccines and medication) were higher in the benchmarking group (Table 4.11). This could be due to the fact that the Sheppard and Edge study was undertaken between March and June, whereas the benchmarking study has measured the impact of both winter and summer growing programmes. Due to the differing production programmes in the benchmarking study there is a considerable variance in bird placement density (Figure 4.25). The average bird placement density was 20.4 birds/m<sup>2</sup> (SD 1.99, IQR 18.7 – 22.8); but individual house/cycle bird weight and bird density at thinning or depletion was not determined as part of this study. These factors vary considerably between sites and the range of bird density suggests that comparing

financial figures per bird may not be the most appropriate benchmarking figure. It has already been demonstrated how stocking density impacts on bird place and energy efficiency (see 4.2.7). In order to measure the effect of changing the parameter the costs were analysed for p/bird and p/kg liveweight. Growers are paid in p/kg liveweight and the data for both studies have been translated to this parameter (Table 4.11).



**Figure 4.25: Comparison of placement density across sites**

The margin results between both studies are comparable. The benchmarking group demonstrated a margin of 1.8 p/bird compared with the 1.9 p/bird determined in the Sheppard and Edge study and a margin of 0.62 p/kg liveweight compared with 0.83 p/kg liveweight. The Sheppard and Edge study is comparing costs and performance to the nearest pence and this approximation at one stage in the calculation creates discrepancies in the data analysis (see Table 4.10) The figures indicate the actual yield could be 2.2 p/bird.

**Table 4.11: Comparison of financial data between p/bird and p/kg liveweight**

Performance indicator	Sheppard and Edge (2006) p/bird	Benchmarking Study p/bird	Sheppard and Edge (2006) p/kg liveweight	Benchmarking Study p/kg liveweight
Chicks p/bird	24.3	24.3	9.6	9.72
Feed p/bird	70.7	70	28.0	28.0
Labour p/bird	4.4	4.4*	1.74	1.76*
Vaccines and vet medicines	1.3	2.21	0.51	0.88
Bedding and litter	1.5	0.70	0.59	0.28
Electricity	1.3	1.20	0.51	0.48
Gas	3.0	3.2	1.19	1.28
Heating oil	0.2	0.2*	0.08	0.08*
Water	0.5	0.2	0.20	0.08
Other variable costs	14.8	14.8*	5.85	5.92*
<b>Total</b>	<b>122</b>	<b>121</b>	<b>48.27</b>	<b>48.48</b>

\* used Sheppard and Edge Standard



The average variance in energy costs between mid-summer and mid-winter crops in the benchmarking group was found to be 1.19 (IQR 1.05 – 1.48) p/kg liveweight which would equate to 3.0 p/bird in the benchmarking study (also see 4.3.5). This factor goes some way to explaining the influence of external air temperature on energy usage.

The benchmarking study was undertaken before the rise in energy costs in the autumn/winter of 2005/06 which has put further pressure on margin. The financial performance described in this thesis demonstrates that the average broiler grower is producing at a profit margin of 1.3%, but even lower if they have a disease challenge, capital repayments, labour costs or rental payments. The individual performance of groups or sites has been considered confidential within the scope of this study and thus cannot be reported.

## 4.5 Performance indicators which can drive real-time analysis

### 4.5.1 Factors affecting water consumption

Water consumption can be affected by a number of interacting parameters (Table 4.12). It is important to consider the source of the water. In the UK, the two main sources are municipal supply, or extraction from a borehole. Water quality including hardness is an important factor to consider when determining water suitability (Manning *et al.*, 2007a). It has been suggested that the salt content and pH of water could affect the administering of vitamins and medication (NAS, 1994 cited in Manning *et al.*, 2007a). The U.S National Research Council produced guidelines on the levels of nutrients and toxins in livestock drinking water (adapted in Table 4.13).

**Table 4.12: Factors that affect water consumption.**

Bird issues	Water quality issues	Feed quality issues	House environmental issues
<ul style="list-style-type: none"> <li>Genetics;</li> <li>Sex;</li> <li>Age;</li> <li>Health or disease challenge</li> <li>Body temperature control.</li> </ul>	<ul style="list-style-type: none"> <li>Hardness;</li> <li>Nitrate levels;</li> <li>Total dissolved solids;</li> <li>Bacterial contamination.</li> </ul>	<ul style="list-style-type: none"> <li>Feed composition and suitability;</li> <li>Feed type;</li> <li>Feed intake;</li> <li>Mycotoxin contamination.</li> </ul>	<ul style="list-style-type: none"> <li>Water temperature;</li> <li>Water pressure;</li> <li>Poorly installed regulators on drinker lines;</li> <li>Type of drinker system;</li> <li>Drinker height (including impact of floor slope);</li> <li>Spillage by birds especially after long dark period if there is jostling at the drinkers;</li> <li>Leakage from drinker system;</li> <li>House temperature;</li> <li>Air velocity;</li> <li>Air humidity.</li> </ul>

**Table 4.13: Guidelines for poultry for the suitability of drinking water (Adapted from NAS, 1994)**

Total Dissolved Solids (TDS) (ppm)	Comments
<1000	Presents no serious issues.
1000 – 2999	Water satisfactory. May cause watery droppings (especially at higher levels) – should not affect health or performance
3000 – 4999	Water poor. May cause watery droppings, increased mortality and decreased growth (especially in turkeys)
5000 – 6999	Water unacceptable – can cause especially at upper limits decreased growth or increased mortality
7000 - 10000	Water unfit for poultry.
> 1000	Water unfit for any livestock

**Primary Source:** National Research Council 1974. Nutrients and Toxic Substances in Water for Livestock and Poultry. Washington D.C: National Academy of Sciences.

Ross (2006) define the maximum acceptable concentration of minerals and organic matter in the water supply and recommend that water complies with these standards (Table 4.14). This has been compared with other research data and demonstrates that there is wide variation within the literature on acceptable mineral content of drinking water for poultry. Further, the UK Drinking Water Standards (DWI, 2006) do not comply with the standards defined for poultry. The levels defined for nitrate, sodium and phosphorous are higher in the human drinking water standard than in the poultry standard (DWI, 2006). Therefore, mains water might comply with the DWI standard, but not be suitable for poultry consumption.

Therefore, water composition and quality can affect consumption levels. It has been previously shown in this thesis that dietary factors can influence water intake and water: feed ratios (see section 4.3.1). Nutritional factors affect water consumption (Manning *et al.*, 2007a) and the consistency and volume of droppings. Enzyme preparations can be added to poultry feed as part of diet formulation to control wet droppings. Vieira and Lima (2005) concluded that birds fed an all vegetarian diet had a higher water intake and produced more excreta which had increased moisture content when compared with a standard diet. It was found in the Vieira and Lima study that the levels of potassium were 20% higher in the vegetarian diet than a diet which includes animal by-products. The all vegetarian diet also increased the total amount of excreta produced per bird by 18%. This factor will increase the risk of microbiological contamination of the litter as the moisture content is higher and potentially increase the incidence of contact dermatitis i.e. breast blisters, hockburn and pododermatitis.

**Table 4.14: Maximum Acceptable levels of Minerals and Bacteria in Poultry Drinking Water (Adapted from Ross, 1999)**

Minerals/ Bacteria	Human Drinking water standard (DWI, 2006)	Acceptable concentration (Ross, 1999)	Comments
TDS (ppm)	1500	300 – 500	-
Hardness (ppm)	No specific standard	-	Watkins (2006) and Fairchild and Ritz (2006) suggest an acceptable level of 110 ppm
Chloride (mg/l)	250	200	Chlorination to between 1 and 3 ppm at drinker level will reduce the bacterial loading. However levels of 14 mg/l can impair performance if Na levels are high (50 mg/l) (Watkins (2006) suggests an average level of 14 mg/l with a maximum acceptable level of 250 mg/l) Fairchild and Ritz (2006) also suggest a maximum acceptable level of 250 mg/l.
pH	5.5 – 9.5	6 – 8	Acid (<pH6) drinking water can affect digestion, corrode drinking equipment and be incompatible with medication and vaccines
Nitrates (ppm)	50	45	Watkins (2006) proposes an average level of 10 ppm with a maximum accepted level of 25 ppm. Fairchild and Ritz (2006) also suggest a maximum acceptable level of 25 mg/l.
Sulphates (ppm)	250	200	High sulphate levels will cause wet droppings. The effect is exacerbated if Na or Mg levels are > 50 mg/l. Watkins (2006) proposes an average level of 125 ppm with a maximum level of 250 ppm. Fairchild and Ritz (2006) also suggest a maximum acceptable level of 250 mg/l.
Iron (mg/l)	0.2	1	Watkins (2006) suggests 0.2 mg/l as an average level with 0.3 mg/l as a maximum level. Fairchild and Ritz (2006) advise a maximum acceptable level of 0.03 mg/l)
Calcium (mg/l)	250	75	Watkins (2006) suggests 60 mg/l as an average level and Fairchild and Ritz (2006) suggest a maximum level of 500 ppm
Copper (mg/l)	2	0.05	Excess copper can impart a bitter taste to the water and cause liver damage. Watkins (2006) suggests an average level of 0.002 mg/l with a maximum of 0.6 mg/l. Fairchild and Ritz (2006) also suggest a maximum acceptable level of 0.6 mg/l.
Magnesium (mg/l)	50	30	High sulphate levels will cause wet droppings. The effect is exacerbated if Na or Mg levels are > 50 mg/l. Watkins (2006) suggests an average level of 14 mg/l with a maximum acceptable level of 125 mg/l. Fairchild and Ritz (2006) also advise a maximum acceptable level of 125 mg/l.
Manganese (mg/l)	0.05	0.05	Fairchild and Ritz (2006) proposes a maximum acceptable level of 0.05 mg/l.
Zinc (mg/l)	5	5	Watkins (2006) proposes a maximum level of 1.5 mg/l.
Lead (mg/l)	0.005	0.05	Watkins (2006) proposes a maximum level of 0.02 mg/l.
Faecal Coliforms	0	0	
Sodium (mg/l)	150	-	Watkins (2006) proposes an average level of 32 mg/l and a maximum level of 50 mg/l. Fairchild and Ritz (2006) also suggest a maximum acceptable level of 50 mg/l.
Phosphorous (mg/l)	2.2	-	Fairchild and Ritz (2006) also suggest a maximum acceptable level of 0.1 mg/l.
Potassium (mg/l)	12	-	Fairchild and Ritz (2006) also suggest a maximum acceptable level of 500 mg/l.

**Primary Source:** WHO.

Air velocity in the poultry houses has been shown to have an impact on broiler performance and feed and water consumption (*May et al., 2000*). High air temperature will inhibit feed

consumption, reduce body weight gain and liveability and increase FCR (Borges *et al.*, 2004). The authors suggest that birds seek to manage heat stress by increasing water consumption and then increasing urinary production. The research has been collated in Table 4.15

**Table 4.15: The relationship between broiler growth performance parameters and water analysis (Adapted from CRRP, 2005 and Barton *et al.*, 1986)**

Growth performance indicator	Statistically significant positive correlation (P < .05)	Statistically significant negative correlation (P < .05)
Feed conversion	Magnesium (Barton <i>et al.</i> , 1986) Sulphate and copper (Zimmermann <i>et al.</i> , 1993)	Calcium (Barton <i>et al.</i> , 1986) Potassium, hardness and conductivity (Zimmermann and Douglass, 1998)
Body weight	Dissolved oxygen, bicarbonate, hardness and magnesium (Barton <i>et al.</i> , 1986)	Nitrate (Barton <i>et al.</i> , 1986)
Liveability	Potassium, chloride and calcium (Zimmermann <i>et al.</i> , 1993) Magnesium, potassium, hardness, and conductivity (Zimmermann and Douglass, 1998)	Calcium, potassium (Barton <i>et al.</i> , 1986)
Rejections	-	Calcium, Nitrate (Barton <i>et al.</i> , 1986) Magnesium, sodium, potassium, hardness, conductivity, phosphate, pH and conductivity (Zimmermann and Douglass, 1998)

Therefore water consumption is influenced by a number of interacting factors.

#### 4.5.2 Factors affecting faecal production

Faeces from the digestive tract of birds mix with urine in the cloaca (Manning *et al.*, 2007a). Antibacterial growth promoters (AGP) have been used historically to control the level of microbiological contamination and enteric pathogens (see section 4.5.4). Site poultry health plans also include vaccination programmes to minimize viral disease and coccidiosis programmes which control necrotic enteritis (NE) and the potential for wet litter. Coccidiostat programmes need to be introduced which ensure that the coccidiostats are rotated to prevent resistance. In Sweden, it was noted that removal of AGP caused faecal production to increase by 2 – 3 % (Ross, 2006).

It was argued by Ficken and Wages (1997) that *Clostridium perfringens* is the causative agent of NE (Manning *et al.*, 2007a). Subclinical NE has also been linked to an increase in FCR (Stuz and Lawton, 1984) and losses due to liver condemnations in Norway have reached 20% (Schaller, 1998). It has been shown that AGP can reduce the ability of *Clostridium perfringens* to cause NE (George *et al.*, 1982). Enteritis and disorders such as “malabsorption syndrome” can result in an increased excretion of water in the faeces (PB1739, 2006 cited by Manning *et al.*, 2007a). Signs of enteritis

are observed from about 15 days into the crop cycle (Pattison, 2002). It is characterised by the production of abnormally wet droppings. The author concludes that some growing sites are regularly affected by enteritis whereas for others it is only an intermittent problem. Long-term therapeutic treatment is not a sustainable solution in the current regulatory, market and financial environment. Therefore management practices need to be defined and controlled that could influence what has also been called “wet litter syndrome”.

Mycotoxin contamination of feed can also cause droppings to be excessively wet (Manning *et al.*, 2007a). They can irritate the digestive tract and impact on kidney performance. Biogenic amines are present in many animal protein products and have been associated with decreased bird performance (Manning *et al.*, 2007a) and correlations between high levels of biogenic amines and decreased efficiency of feed utilisation have been reported in poultry. (NAS, 1994 citing Keirs and Bennett, 1993). Biogenic amines have also been implicated in malabsorption syndrome (Barnes *et al.*, 2001). This syndrome is characterised by an increase in FCR, decreased weight gain and enlargement of the proventriculus. It can also cause an increased incidence of gastrointestinal rupturing during processing which then leads to carcase contamination.

Feed passage i.e. the presence of undigested food in the faeces of broilers has also been a major issue (Butcher *et al.*, 2002). This resulted in poor feed conversion, reduced body weight and poor flock conformity (CV). The condition has been seen as a problem for individual grower sites or for integrators. A number of these factors have already been suggested as causal agents of malabsorption syndrome or “wet-litter” in this thesis. The factors which can cause an increase in water consumption and/or the level of faecal material whether nutritional or environmental will therefore impact on litter quality and subsequently the incidence of contact dermatitis.

#### **4.5.3 Factors affecting litter quality and contact dermatitis**

Problems associated with wet litter include increased ammonia levels; health problems and contact dermatitis (Table 4.16). Coccidial, bacterial such as *Escherichia coli*, or viral infections can cause poor litter conditions to occur (see 4.5.2). Martrenchar *et al.*, (2002) in their study on foot pad dermatitis (citing Ekstrand *et al.*, 1998, Harms *et al.*, 1977 and Harms and Simpson, 1982) argue

that lesions can be related to food supplier and biotin deficiency and also suggest that the level of lesions can be reduced by reducing supplemental salt in the diet (see 4.5.1). Defra stated that any poultry disease or skeletal leg abnormality that reduces the birds' mobility is likely to affect welfare adversely, as birds will have increased contact with litter. Litter moisture can be affected by drinker design; air change rate; condensation due to incorrect insulation; litter material and depth; stocking density; diet and flock health (PB1739, 2006).

**Table 4.16: Factors that affect wet litter.**

Nutritional issues	Environmental issues	Contamination
<ul style="list-style-type: none"> <li>• High mineral consumption through water or feed can increase water consumption;</li> <li>• Excess protein;</li> <li>• Imbalance of amino acids;</li> <li>• Poor quality protein;</li> <li>• High levels of NSP (non-starch polysaccharides);</li> <li>• Poor quality dietary fat;</li> </ul>	<ul style="list-style-type: none"> <li>• Environmental control such as ambient temperature and humidity;</li> <li>• Drinker system management to prevent leaks or spillage;</li> <li>• Type of bedding material;</li> </ul>	<ul style="list-style-type: none"> <li>• Bacterial, coccidial or viral infections;</li> <li>• Biogenic amines;</li> <li>• Presence of mycotoxins in the feed;</li> </ul>

The conclusions reached by Defra (PB 1739, 2006) with regard to litter quality and contact dermatitis are summarised as follows:

- Interacting factors affect the condition of poultry litter. Their detrimental effects are **additive** (this has been previously described in sections 4.5.1 and 4.5.2);
- Poor quality and excess protein levels in the feed increase litter moisture and its nitrogen content which can lead to an increase in contact dermatitis. This will occur if the nitrogen level in the litter exceeds 5.5%;
- Dietary sodium, chloride and potassium affect water consumption and therefore litter moisture and condition. Their inclusion levels in the feed must be optimal.
- The maximum inclusion rates of dietary ingredients should reflect their individual and additive effects on the litter; and
- Either poor quality fat or an excess of good quality fat will lead to higher oil levels in the litter which causes it to lose its friability and therefore to cap.

#### 4.5.4 AGP

AGP were used commercially because of the beneficial effects on performance and mortality (Ross, 2006 citing Rosen, 1995). On 14<sup>th</sup> December 1998, the European Council of Agriculture Ministers voted to withdraw authorisation (Council Directive 70/524/EEC with effect from 01 July

1999) for four antibiotics used as prophylactic growth promoters. This was adopted by the ACP in 1999. There was a complete ban in the EU from 01 January 2006. Ross (2006) also report that removal of AGP reduced growth rate and increased FCR (Table 4.17). Wierup (2001) suggests that the AGP ban in Sweden has had an adverse effect on animal health and welfare and financial performance. There has also been an increase in the use of therapeutic antibiotics (Casewell *et al.*, 2003). Price *et al.*, (2005) suggested that chickens grown without antibiotics are less likely to carry antibiotic-resistant strains of *Campylobacter*. Philips *et al.*, (2004) argue that the banning of antibiotic usage for livestock based on the "precautionary principle" can be ineffective or even harmful to human and animal health if it is not undertaken with a full quantitative risk assessment. They suggest that control of antibiotic usage must be within a framework of improved hygiene and biosecurity at all stages of the poultry supply chain.

**Table 4.17: Effect of removal of antibiotic growth promoters (maxus) on performance of Ross 308 in 3 trials carried out in 1998 (Source Ross, 2006)**

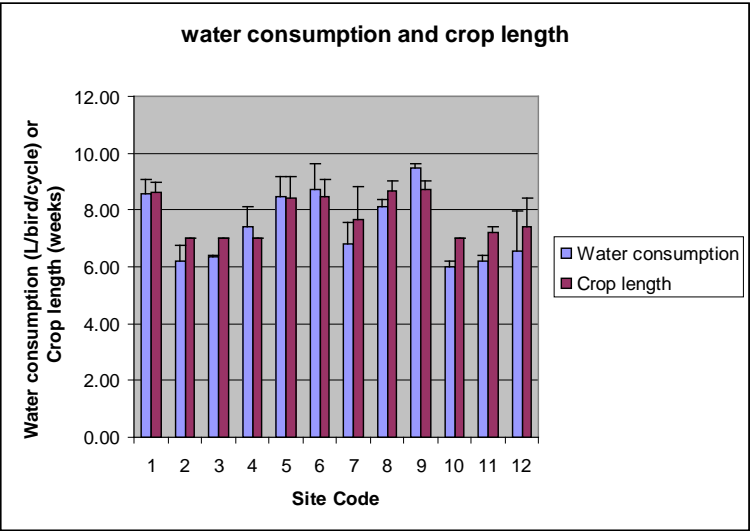
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Alternative measures to antibiotic usage have been investigated and these include competitive exclusion (Barnes *et al.*, 1980) with some success; probiotics (cultures of beneficial organisms) and pre-biotics (food ingredients that selectively stimulate growth of certain bacterial flora) and supplementary enzymes (Kaldhusdal, 2003). Organic acids are routinely used to control bacterial contamination of whole wheat feed. Other feed ingredients which may prove beneficial include plant derived products, and feed form, cereal type and far source have also been shown to affect *C. perfringens* activity. Management practices such as feeding regimes, stocking density, lighting programmes, litter type and terminal hygiene programmes have also been shown to influence *C. perfringens* activity (Kaldhusdal, 2003).

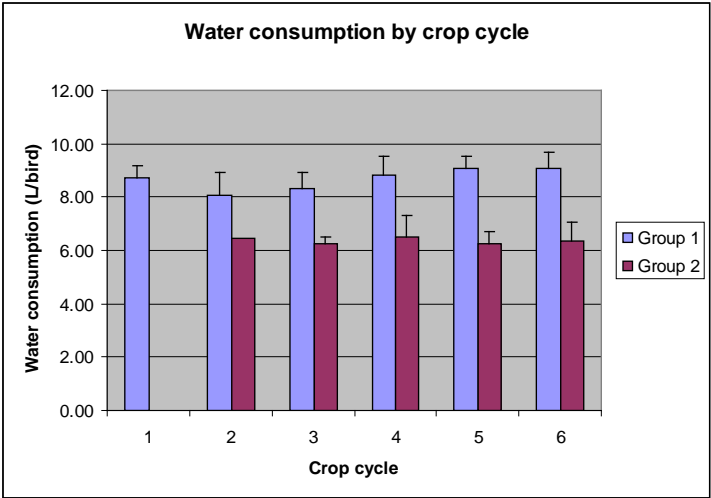
#### **4.5.5 Analysis of water consumption data by site**

Total water consumption per crop was discussed in 4.3.1 where a strong correlation was identified between average water consumption per site and average crop length ( $r = 0.80$ ,  $r^2 = 0.64$ ) i.e. the older the bird, the more that it drinks. This parameter has been suggested as a measure of

value when considering environmental performance of the site (IPPC BREF, 2003). The total water consumption has been shown to vary by site, by group and by season (Figures 4.15, 4.26, 4.27, 4.28 and 4.29) and each site has been shown to have a different water consumption profile in terms of L/bird per cycle.



**Figure 4.26: Comparison of average water consumption per crop by site against crop length**



**Figure 4.27: Comparison of average water consumption per crop cycle by group**

The factors that affect the degree of water consumption by site in L/bird/cycle have been previously discussed (see 4.5.1). The variation on the original case study site was assessed over two benchmark years and showed a variation between years (in litres per bird) even though the bird residence period was the same (Table 4.18). The variance equates to 0.5 L/bird.



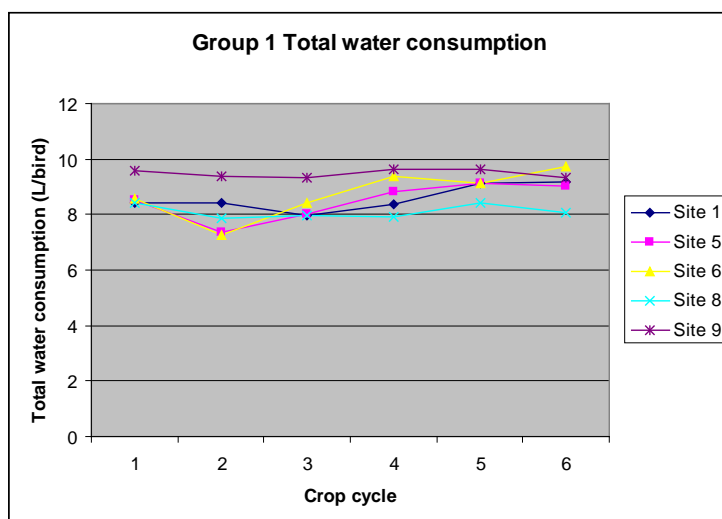


Figure 4.28: Comparison of water consumption by site per crop cycle for group 1

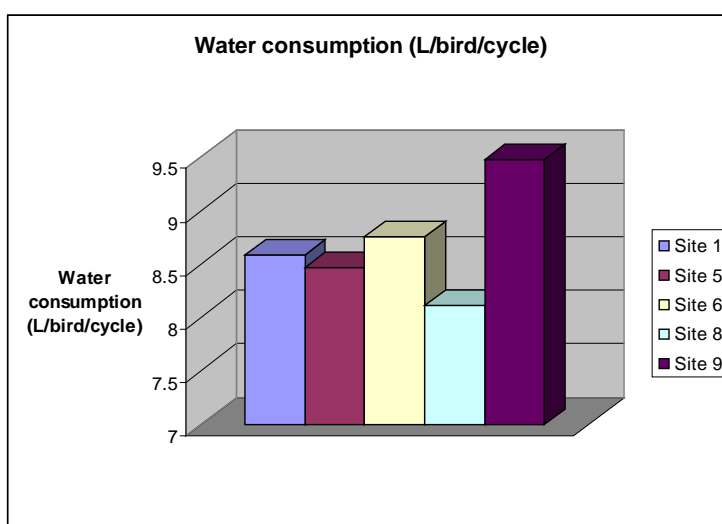


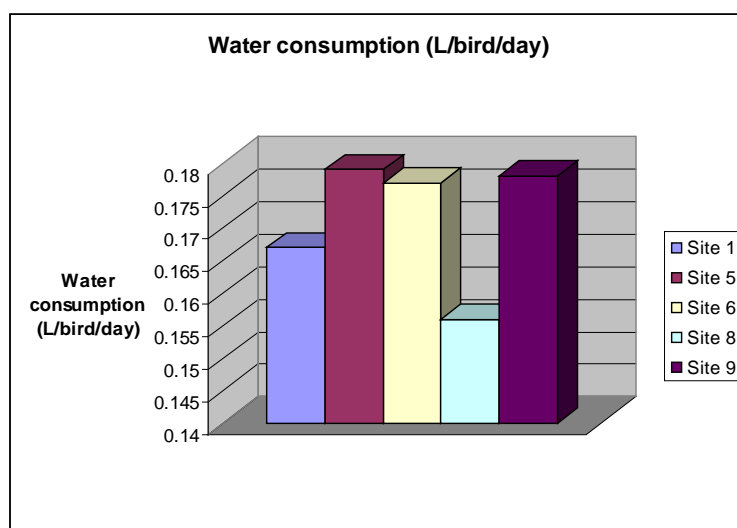
Figure 4.29: Comparison of average water consumption indicators (L/bird/cycle) by site

The water consumption profile for five of the sites in Group 1 have been compared by crop cycle in L/bird/day (Table 4.19) and shows a variance between sites (see Figure 4.30); and also in terms of L/m<sup>2</sup> floor area (Figure 4.31). These parameters are worthy of further study to determine which is the best parameter to use as a benchmarking indicator for total water

Table 4.18: Drinking water consumption on case study site for two benchmark years.

Crop date	start/end	Jul 02 – Sep 02	Sep 02 – Nov 02	Dec 02 – Jan 03	Feb 03 – Mar 03	Annual 2002	IPPC BREF (2003)
Usage (L/bird/cycle)		7.7	7.3	7.4	7.4	7.6	4.5 - 11
Crop date	start/end	Aug 04 – Oct 04	Oct 04 - Dec 04	Dec 04 – Feb 05	Feb 05 – Apr 05	Annual 2004	IPPC BREF (2003)
Usage (L/bird/cycle)		7.8	8.0	8.0	7.9	7.9	4.5 - 11

consumption. The data from the benchmarking group has been analysed for Group 1 mean water consumption = 8.68 L/bird per cycle (SD 0.50, IQR 8.47 – 8.75) and Group 2 mean water consumption = 6.39 L/bird per cycle (SD 0.55, IQR 6.11 – 6.56).



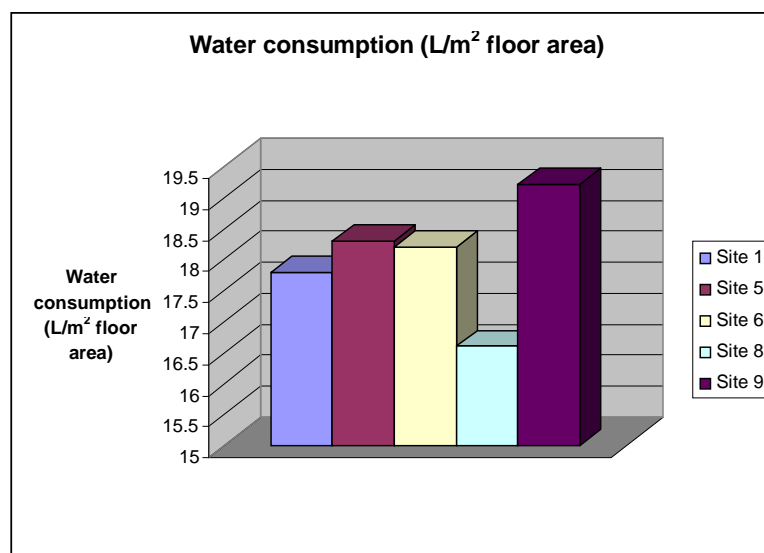
**Figure 4.30: Comparison of average water consumption indicators (L/bird/day) by site**

The two groups were compared using sem and there was a statistically significant difference ( $p = 0.05$ ) between the two groups. Therefore this parameter cannot be used to compare site performance from different production systems unless there is an adjustment factor used for the influence of bird residence period.

**Table 4.19: Comparison of water consumption (L/bird/day) for five Group 1 sites**

Site	Water consumption (L/bird/day)					Average
	1	5	6	8	9	
<b>Crop</b>						
1	0.159	0.167	0.168	0.156	0.184	0.167
2	0.159	0.139	0.137	0.151	0.177	0.153
3	0.156	0.228	0.221	0.153	0.170	0.186
4	0.155	0.172	0.177	0.158	0.175	0.167
5	0.186	0.183	0.183	0.162	0.189	0.181
6	0.188	0.184	0.187	0.158	0.176	0.179
<b>Average</b>	<b>0.167</b>	<b>0.179</b>	<b>0.177</b>	<b>0.156</b>	<b>0.178</b>	

The data has also been assessed in terms of L/m<sup>2</sup> floor area and for Group 1 mean water consumption = 17.9 L/m<sup>2</sup> floor area (SD 1.60, IQR 16.8 – 18.8) and Group 2 mean water consumption = 19.5 L/m<sup>2</sup> floor area (SD 1.79, IQR 18.6 – 20.2). Using sem there was a statistically significant difference ( $p = 0.05$ ) between the two groups in terms of L/m<sup>2</sup> floor area mainly because of the difference in bird density between the two groups, group 2 having the higher bird density. Data was also analysed in terms of L/bird/day.



**Figure 4.31: Comparison of average water consumption indicators (L/m<sup>2</sup> floor area) by site**

Group 1 had a mean water consumption of 0.167 L/bird/day (SD 0.015, IQR 0.157 – 0.181) and Group 2 had a mean water consumption of 0.154 L/bird/day (SD 0.024, IQR 0.142 – 0.156). There was no statistically significant difference between Group 1 and Group 2 in terms of L/bird/day ( $p = 0.05$ ). This suggests that in order to address the effect of stocking density (birds/m<sup>2</sup>) and bird residence period (days) when comparing different production systems the parameter L/bird/day might be a better indicator than the current IPPC BREF indicator of L/bird/cycle. These results require further study in a future refinement of the QA model.

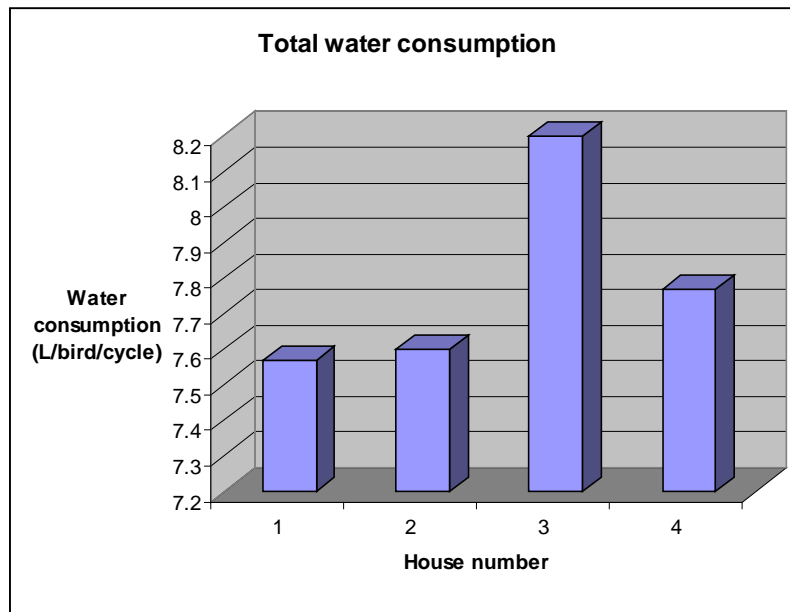
#### 4.5.6 Analysis of water consumption data by house

It has been assumed so far in the research that water consumption is uniform across the site in each house. In order to quantify the level of variance between houses on the site the water usage during the bird residence period for crop cycle “4” was been analysed on the case study site from Study B. The average site water consumption for the crop was 7.95 L/bird/cycle. Table 4.20 demonstrates the variance between houses and suggests that House 3 has higher water consumption than the other three houses.

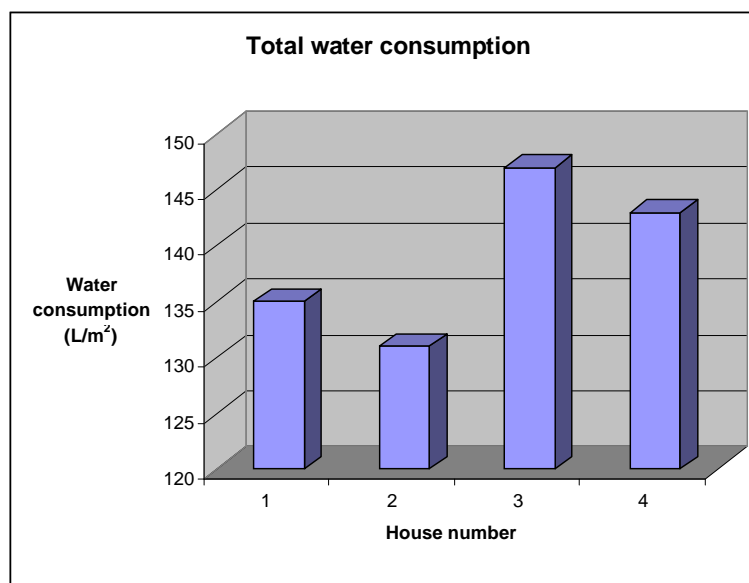
**Table 4.20: Comparison of data using different water consumption parameters**

House	Total Water consumption (L/bird/cycle)	Total Water consumption (L/m <sup>2</sup> )	Total Water Consumption (L/bird/day)
One	7.57	135	0.158
Two	7.60	131	0.162
Three	8.20	147	0.164
Four	7.77	143	0.159

The three water consumption parameters have been used to analyse total water consumption by house (Figures 4.32, 4.33 and 4.34).

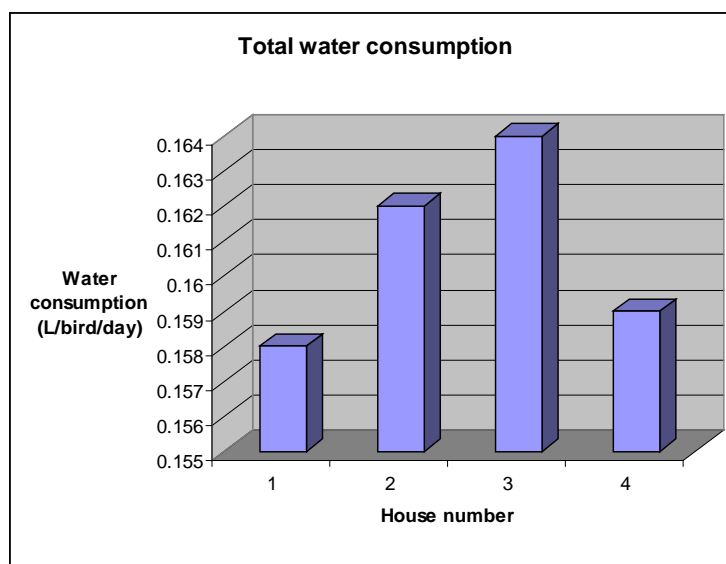


**Figure 4.32: Comparison of water consumption indicators (L/bird/cycle) by house crop "4"**



**Figure 4.33: Comparison of water consumption indicators (L/m²) by house crop "4"**

The correlation coefficient for each parameter was determined (Table 4.21) and the results show that whilst there was a strong correlation between L/bird/cycle and L/m² with houses on the site (as the stocking density is the same) but there was a weak correlation between L/bird/cycle and L/bird/day; and L/m² and L/bird/day. This mirrors the results of the assessment of correlation between water consumption indicators in the group results.



**Figure 4.34: Comparison of water consumption indicators (L/bird/day) by house crop “4”**

In order to determine when in the crop cycle there was a variance in total water consumption between the houses, daily water consumption was considered and compared. Daily water consumption is already routinely monitored by growers as an aid to monitoring bird health and welfare.

**Table 4.21: Correlation between different water consumption parameters**

	Total Water consumption (L/m <sup>2</sup> )	Total Water Consumption (L/bird/day)
Total Water consumption (L/bird/cycle)	$r = 0.88$ , $r^2 = 0.78$ (significant at 3 degrees of freedom $p = 0.05$ )	$r = 0.72$ , $r^2 = 0.52$ (not significant at 3 degrees of freedom $p = 0.05$ )
Total Water consumption (L/m <sup>2</sup> )		$r = 0.33$ , $r^2 = 0.11$ (not significant at 3 degrees of freedom $p = 0.05$ )

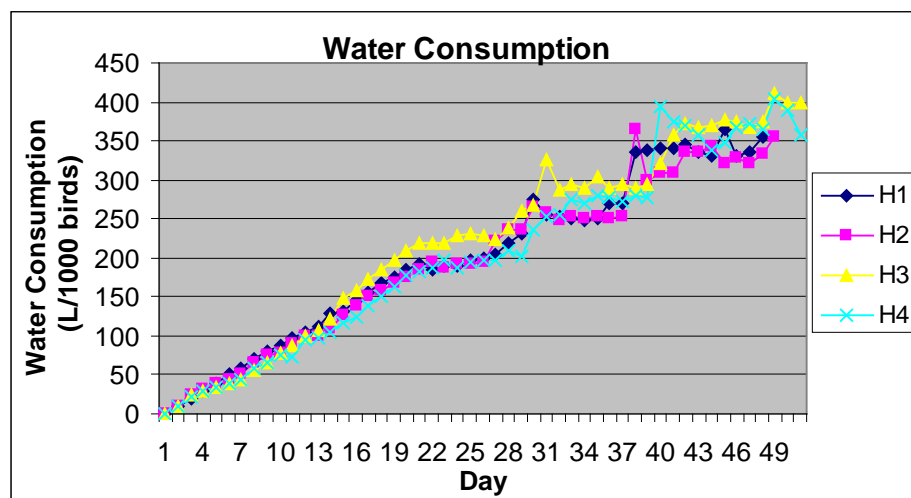
The study aimed to determine whether daily water consumption could be used as a headline indicator which gives an insight into bird behaviour and bird performance with regard to growth, FCR, reject levels or contact dermatitis.

#### 4.5.7 Daily water consumption

The average daily water consumption has been assessed for the case study site over four crop cycles ( $n = 16$ ). The results indicate that the water consumption is not a steady rise as expected by both the internal standard and Goan (1992). Indeed the levels of water consumed increase after the first seven to ten days (Figure 4.35) and this peak reduces again around 22 days (Manning *et al.*, 2007b).

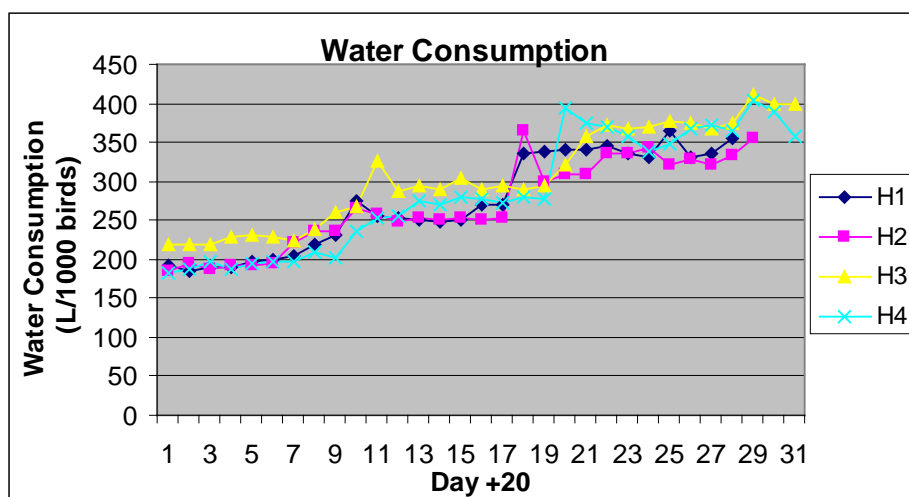
**Figure 4.35: Daily water consumption on case study site compared to standard figures (Manning *et al*, 2007b)**

The daily water consumption by house for crop cycle 4 has been plotted to determine the degree of variation between the houses (Figures 4.36 and 4.37).

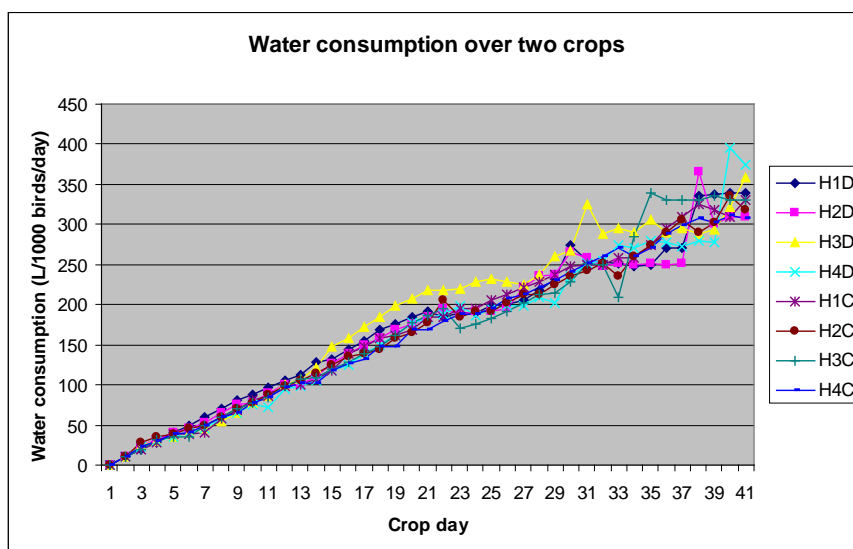


**Figure 4.36: Daily water consumption by house for poultry crop cycle 4**

House 3 showed a higher daily water consumption between days 13 and 25 in crop cycle 4. When compared to the previous crop cycle (Figure 4.38) water consumption for House 3 (in crop cycle 4) again appears high over that time period. The actual daily water consumption for House 3 (in crop cycle 4) has been compared to the average daily consumption for the other seven houses (across the two crop cycles) using the Chi-squared test to determine the degree of significance of the variation. House 3 had an  $\chi^2$  of 132.55 and this was deemed significant at  $p = 0.01$ .

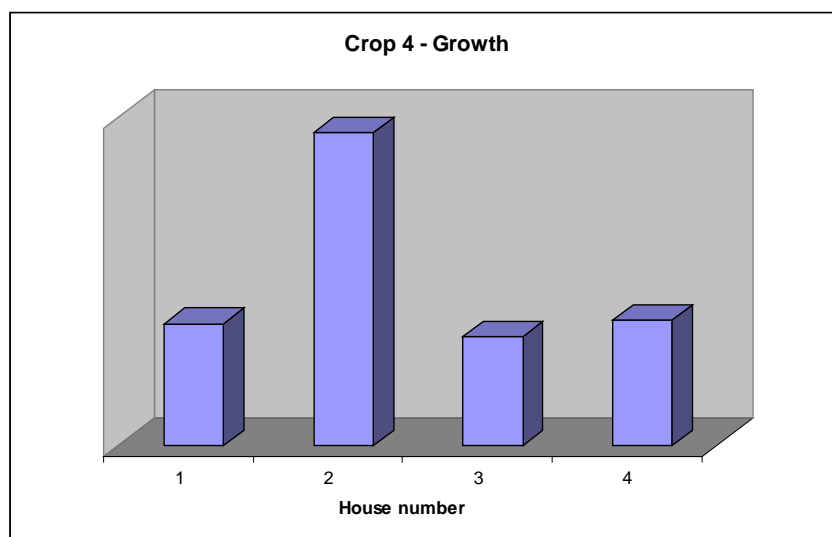


**Figure 4.37: Daily water consumption by house from Day 20 for crop cycle 4**

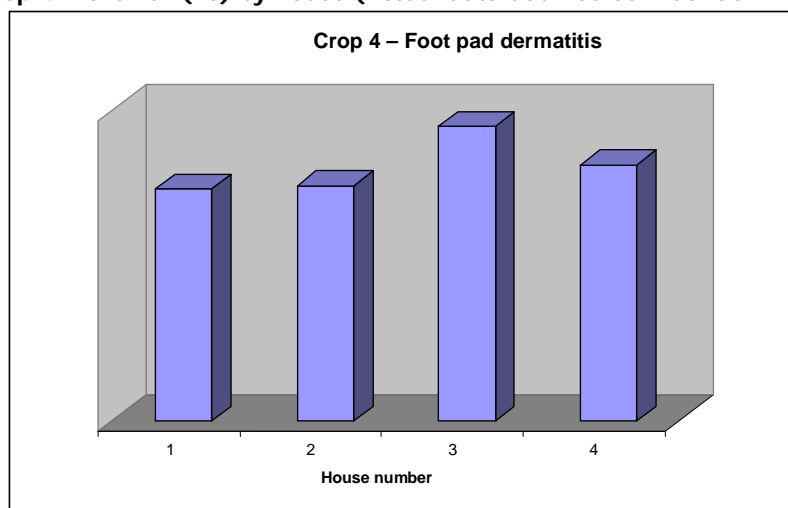


**Figure 4.38: Daily water consumption by house for Crops 3 and 4**

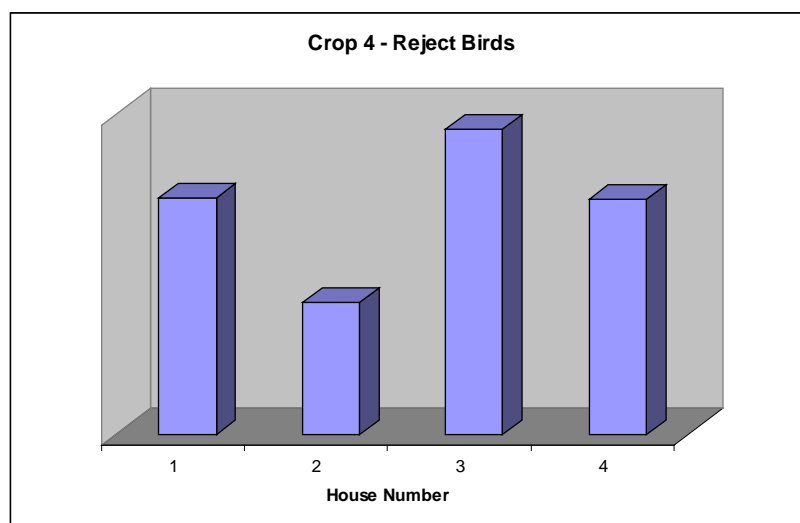
Further performance indicators have been assessed for crop cycle 4 to determine if the increased water consumption correlated with poor performance with regard to other key indicators (see 4.5.2 where it has been argued that changes in water consumption have been linked to incidence of enteritis and contact dermatitis as a result of the deterioration of litter quality). KPI including foot pad dermatitis (%), reject levels (%), and growth (%), have been analysed for crop cycle 4 (Figures 4.39, 4.40. and 4.41). The results indicate that House 3 is the poorest performing house for all criteria. The exact data has not been identified on the graph Y-axis as this has been deemed confidential. The intra-crop correlation coefficient has been used to determine the degree of significance of the interaction of the variables in Crop 4 (Table 4.22).



**Figure 4.39: Crop 4 – Growth (%) by house (Actual data deemed confidential in this study)**



**Figure 4.40: Crop 4 – Foot pad dermatitis (%) by house (Actual data deemed confidential in this study)**



**Figure 4.41: Crop 4 – Reject Birds (%) by house**



The statistical analysis indicates that there is weak correlation between growth (%) and water consumed in terms of all three water consumption parameters (Table 4.22). There was a weak correlation between water consumption in terms of L/bird/day and foot pad dermatitis and reject levels. However there was a positive, significant correlation between foot pad dermatitis (%) and total water consumed in terms of L/bird/cycle and L/m<sup>2</sup>; and reject levels (%) and total water consumed in L/m<sup>2</sup> (at p = 0.05). The correlation between water consumption and foot pad dermatitis was only found on an intra-crop rather than inter-crop basis. This suggests that the factors associated with a particular crop on a particular site were not necessarily replicated in the next crop cycle i.e. influences of water consumption, ventilation, diet, disease challenge etc varied from crop to crop. It should be noted that no correlation was found when the incidence of foot pad dermatitis was below an average of 12% per site. However where foot pad dermatitis was present above 12% there was an intra-crop correlation between water consumption in L/m<sup>2</sup> and foot pad dermatitis.

**Table 4.22: Correlation between water consumption parameters for Crop 4**

	Total Water consumption (L/bird/cycle)	Total Water consumption (L/m <sup>2</sup> )	Total Water Consumption (L/bird/day)
Foot pad dermatitis (%)	$r = 0.99, r^2 = 0.98$ (Significant)	$r = 0.91, r^2 = 0.83$ (Significant)	$r = 0.70, r^2 = 0.49$ (NS)
Reject (%)	$r = 0.79, r^2 = 0.62$ (NS)	$r = 0.88, r^2 = 0.78$ (Significant)	$r = 0.16, r^2 = 0.03$ (NS)
Growth (%)	$r = -0.50, r^2 = 0.25$ (NS)	$r = -0.76, r^2 = 0.58$ (NS)	$r = 0.24, r^2 = 0.06$ (NS)

NS = not significant at 3 DOF

The volume of water consumed in L/m<sup>2</sup> has been analysed for five crops (Table 4.23) and demonstrates a consumption of between 1 and 23% higher in House 3 than the average (excluding House 3) per crop cycle.

**Table 4.23: Comparison of water consumption by house by crop in L/m<sup>2</sup>**

Crop No	House 1	House 2	House 3	House 4	Average
	Water consumption (L/m <sup>2</sup> )				
1	138	140	164 (14%)	154	149
2	147	145	178 (23%)	143	153
3	132	134	135 (1%)	136	134
4	135	131	147 (8%)	143	139
5	137	139	145 (4%)	141	141

Figure in brackets is the percentage water consumption above average of houses 1, 2 and 3

Due to the confidential nature of the data, the four houses have been categorised into Bands A to D, the best performing being Band A and the poorest Band D for the four crops for each performance indicator. If the data is identical or within three decimal places as a percentage,

criteria have been given the same banding. The results demonstrate the poorer performance of House 3 compared to other houses on the site (Table 4.24). It should be noted though that in crop cycle 3, House 3 did not have a significantly different pattern in water consumption (Figure 4.37) but showed a slight drop in consumption at Day 23.

**Table 4.24: Comparison of performance data with water consumption for four crop cycles.**

House 4					
Crop Cycle	Foot pad dermatitis (%)	Reject (%)	Growth (%)	Water consumption (L/bird)	Water (L/m <sup>2</sup> )
1	A	C	C	A	B
2	B	A	A	B	A
3	D	D	D	D	D
4	C	B	B	C	C
Notes	Highest D	Highest D	Lowest D	Highest D	Highest D
House 3					
Crop Cycle	Foot pad dermatitis (%)	Reject (%)	Growth (%)	Water consumption (L/bird)	Water (L/m <sup>2</sup> )
1	A	C	C	A	B
2	B	B	B	B	A
3	C	D	D	D	C
4	C	A	A	C	C
House 2					
Crop Cycle	Foot pad dermatitis (%)	Reject (%)	Growth (%)	Water consumption (L/bird)	Water (L/m <sup>2</sup> )
1	A	B	A	A	C
2	C	D	D	B	B
3	D	A	B	D	D
4	B	C	C	B	A
House 1					
Crop Cycle	Foot pad dermatitis (%)	Reject (%)	Growth (%)	Water consumption (L/bird)	Water (L/m <sup>2</sup> )
1	A	D	B	A	A
2	B	A	A	B	B
3	D	C	C	D	D
4	C	B	D	C	C

Having analysed the data to the level described in Table 4.24, management practices including utilising the humidity thermostat to drive the ventilation were implemented in House 3 for crop cycle 5. Analysis of the data (Figure 4.42) shows that in crop cycle "5" House 3 did not experience the rise in water consumption between Days 13 to 25, but as observed in Crop 3 saw a slight drop, in consumption. House 3 was in the D band for two out of five factors for crop cycle 5 (Table 4.25). The data suggests that there is some inherent performance issue associated with House 3 which is worthy of further investigation. The houses have been rated according to the

performance criteria in Tables 4.20 and 4.21 and the number of times they were in the best performing category Band "A" (Table 4.26).

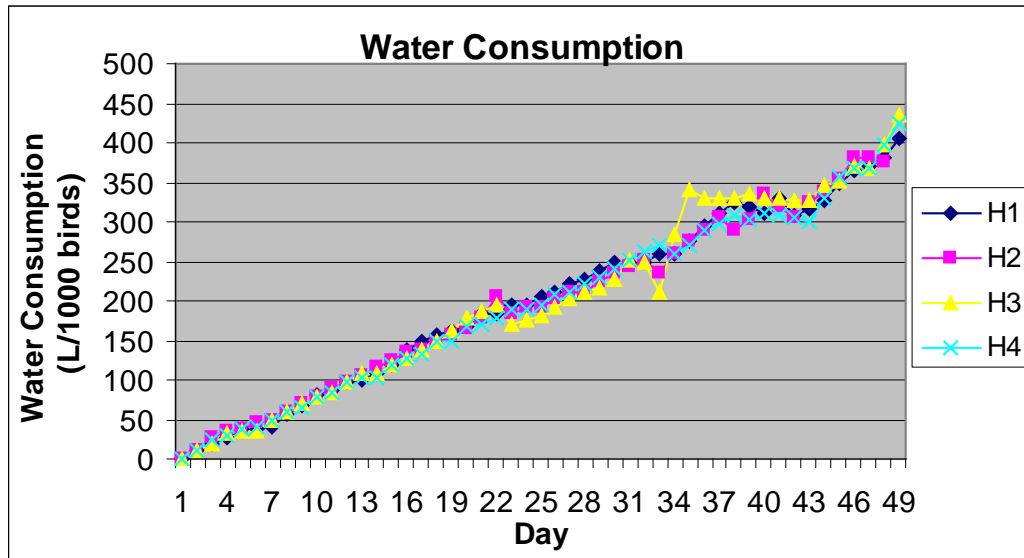


Figure 4.42: Daily water consumption by house for crop cycle 5

House 3 and House 4 are the two poorest performing houses in terms of the indicators described.

Table 4.25: Comparison of performance data for crop cycle 5.

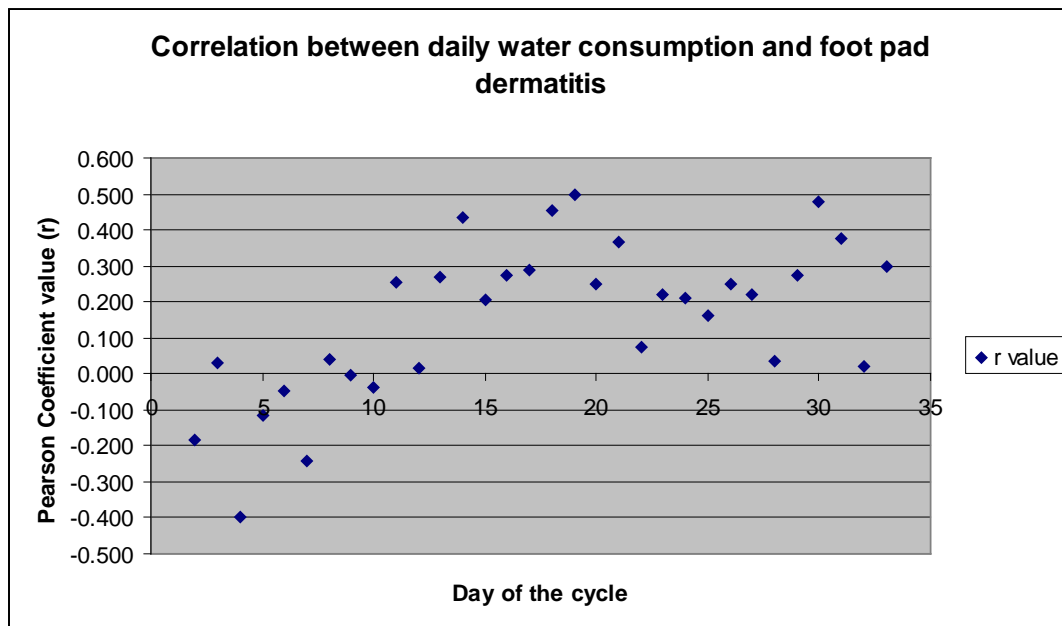
Cycle 5 House	Foot pad dermatitis (%)	Reject (%)	Growth (%)	Water consumption (L/bird)	Water (L/m <sup>2</sup> )
1	A	A	A	B	A
2	B	B	B	A	B
3	C	B	C	D	D
4	D	B	D	B	C

Table 4.26: Comparison of individual house performance on the case study site

House	Percentage of results in Band A over five crop cycles
1	56
2	28
3	04
4	12

The correlation between foot pad dermatitis at 38 days and at 52 days was  $r = 0.76$  for eight crop cycles ( $n = 32$ ) which is significant at  $p = 0.05$ . This could imply that age of slaughter is not a critical factor when determining the degree of foot pad dermatitis for a thinned bird production system. The correlation between water consumption on a given day of the crop cycle and foot pad dermatitis at 38 days was also determined ( $n = 16$ ) over four crop cycles (figure 4.43). There was a weak negative correlation ( $r = -0.40$ ) at day four; significant correlation ( $p = 0.05$ ) at day

fourteen ( $r = 0.44$ ); day eighteen ( $r = 0.46$ ) and day nineteen ( $r = 0.50$ ) and day thirty ( $r = 0.49$ ).



**Figure 4.43: Correlation between water consumption and foot pad dermatitis**

On an intra-crop basis the correlation between daily water consumption and foot pad dermatitis was analysed at confidence level  $p = 0.05$ , and significant positive and negative correlation was determined at some days in the crop cycle (Table 4.27). The results demonstrate that this is an intra-crop phenomenon and that different factors are influencing daily water consumption in each crop cycle. However certain days of the crop cycle show a significant correlation with footpad dermatitis. Pattison (2002) stated that signs of enteritis are observed from about 15 days into the crop cycle. The correlation results would also indicate that increased water consumption which can lead to wet litter is apparent between days 14 and 17. The impact of medication on the correlation factors has not been considered in this study i.e. that birds were treated for signs of enteritis which then had an impact on water consumption and the degree of correlation. A clear pattern does not emerge from these results but they suggest that this relationship is worthy of further study in order to determine if a drop or increase in water consumption in the first week of the crop cycle or a sudden increase/decrease in days 14 - 30 are related to enteritis and litter quality. The study has been able to demonstrate that there is a correlation between total water consumption and the incidence of foot pad dermatitis and factory rejects.

**Table 4.27: Comparison of the correlation between daily water consumption and foot pad dermatitis on an intra crop basis.**

Day	Crop 1	Crop 2	Crop 3	Crop 4
5				-0.80
6	0.94		0.88	-0.94
7	0.94			
9	-0.94			
12	0.85			
14		0.89		-0.85
15	-0.81	0.85	-0.95	
16	-0.80	0.88	-0.96	
17	-0.85	0.93	-0.81	-0.90
18		0.95		
19		0.99		
20		0.97		-0.94
22	-0.86	0.89		
23	-0.82	0.91		0.92
24	-0.94	0.97	-0.80	
25	-0.94	0.97	-0.80	
26	-0.96		-0.82	0.91
27	-0.84			
28	-0.88			
29	-0.90			-0.99
30		0.91		
31		0.95		-0.95
32				-0.86
33				-0.90
35		0.83		
36		0.94		

It has also shown that there is a multifactorial influence effect on water consumption and litter quality which is difficult to analyse in a commercial situation. The benefits of process-orientated benchmarking using daily water consumption is worthy of further study as it is easy to measure and record and could be used as a headline indicator. Daily water consumption is currently monitored in L/bird/day. It has been shown in this study that L/m<sup>2</sup> is a good end of crop indicator of water consumption. More work should be undertaken to determine the threshold level in terms of L/m<sup>2</sup>/day at which there is a resultant impact on litter quality. This may be influenced by the degree of absorbency of the litter material and the ventilation profile. This performance indicator would then provide managers with a “trigger-point” at which they need to take action to minimise foot pad dermatitis. Further work should be undertaken to determine the degree of correlation which was identified in three of the four crop cycles around day six. In the event of a sudden rise or fall in water consumption between days 14 and 25 when compared to either the expected

water consumption and/or the other houses on the site action can also be taken within the crop cycle to try to address potential health issues and improve litter quality. These actions can include for example bird health assessment, checks for water leaks, or incorrect performance of drinkers, high house temperature, the need for addition of extra litter material, and/or a change in ventilation profile in order to improve litter quality. The research also demonstrates that whole site performance data, whilst of benefit, can also mask the performance of individual houses on the site which can have a major impact on overall site performance.

#### 4.5.8 Leg health

Leg culls have been previously discussed (see 4.2.3). It is essential within any responsive bird management system to utilise leg health performance indicators such as % leg culls or gait scoring in order to determine leg health status on a daily basis. Gait scoring (Table 4.28) is a proven method for assessing the ability of broilers to walk as defined by Kestin *et al.*, (1992) and Dawkins *et al.*, (2004). Grandin (2005) further defines an acceptable gait score standard as 95% of the birds can walk evenly for 10 steps. Genetic selection has a major impact on leg disorders (Jordan, Pattison *et al.*, 1996); continuous light has been shown to cause an increase in leg problems compared to intermittent lighting programmes, although light source has been shown to have no effect. The authors further asserted that lighting programmes with an appropriate dark period can reduce the incidence of leg disorders, possibly as a result of increased exercise. Intermittent lighting programmes can also improve feed utilisation.

**Table 4.28: Gait Scoring**

Score	Description Kestin <i>et al.</i> , (1992)	Description Dawkins <i>et al.</i> , (2004).
0	Normal	Normal – walks at least ten steps with ease and is well balanced
1	Slight defects	Walks abnormally for at least ten steps with an uneven stride and is unbalanced
2	Definite and identifiable defect in the gait	Reluctant to walk or not able to walk. Birds that walk only 1 to 4 steps would be scored as 2's
3	Obvious defect – limping, unsteady, splayed legs	
4	Severe gait defect – only walk with difficulty when driven or strongly motivated	
5	Incapable of walking on their feet	

This is thought to be due to improved digestion in periods of dark. Defra state that birds should have a minimum of eight hours artificial light each day and have a dark period for a minimum of

30 minutes per day (Defra, 2002b). Kestin *et al.*, (1992) suggested that leg weakness in commercial broilers was related to rapid juvenile growth rate and that there was a strong correlation between leg weakness and growth rate. This research study has shown similar results with a strong correlation between body weight and leg culls (Table 4.29) ( $r = 0.56$ ,  $r^2 = 0.32$ ) which is deemed statistically significant at  $p = 0.05$  (DOF = 49).

**Table 4.29: Linear regression of TD and GS on body weight (Adapted from Kestin *et al.*, 1992)**

	Cross	Intercept	Regression coefficient	R square
Tibial Dyschondroplasia (TD)	1	-0.317	0.358	0.033
	2	-0.185	0.269	0.016
	3	-0.169	0.206	0.013
	4	-0.517	0.525	0.035
Gait Score (GS)	1	-1.919	2.038	0.281
	2	-1.742	1.986	0.243
	3	-0.290	1.368	0.122
	4	-0.954	1.620	0.146
Body weight vs. leg culls (Research study)		<b>-1.99</b>	<b>1.107</b>	<b>0.316</b>

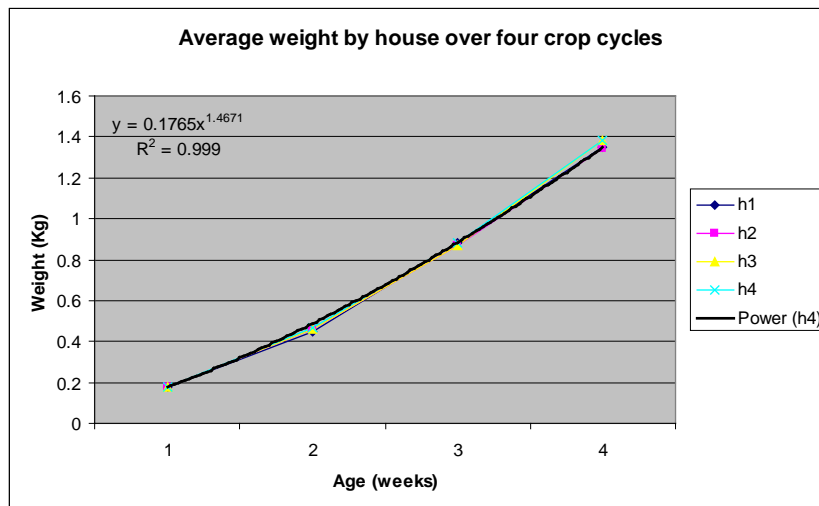
#### 4.5.9 Growth rate and crop fill

The use of average weight of birds as a performance indicator has been previously discussed (see 4.2.6). The mean bird weight for all sites ( $n = 12$ ) was 2.47 kg (SD 0.28, IQR 2.15 – 2.70) and the mean bird weight for all crops ( $n = 64$ ) was 2.50 kg (SD 0.30, IQR 2.16 – 2.72). The average weight profile at 7, 14, 21 and 28 days has been recorded over four crop cycles by house for the case study site (Figure 4.44). The line of best fit for each of the four houses has been defined (Table 4.30) where  $x$  = bird age in weeks and  $y$  = average weight in kg.

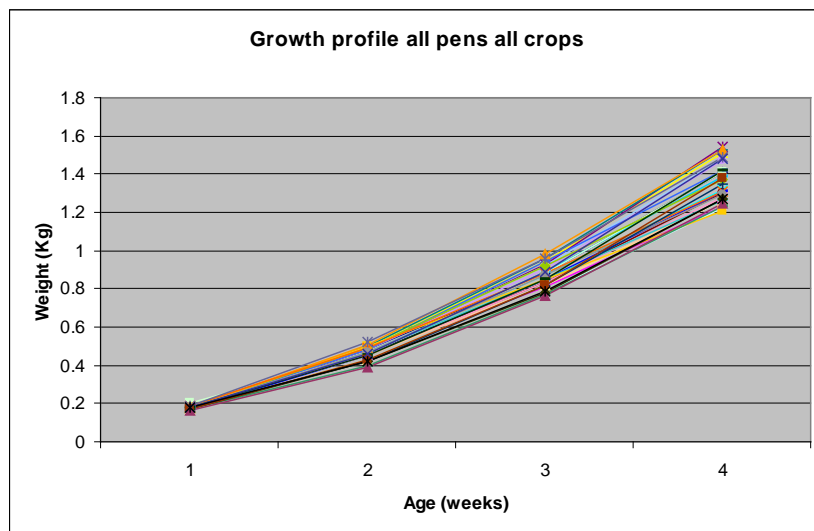
**Table 4.30: Comparison of bird weight with age in weeks to determine individual house performance on the case study site**

House	Formulae	$r$	$r^2$
1	$y = 0.177x^{1.47}$	0.99	0.99
2	$y = 0.176x^{1.45}$	0.99	0.99
3	$y = 0.175x^{1.47}$	0.99	0.99
4	$y = 0.177x^{1.47}$	0.99	0.99

Although the average growth rate by house demonstrates close correlation, there is large variation between the different sexed pens on the case study site (Figure 4.45). The correlation between 0, 7, 14, 21 and 28 day weights had been assessed for the twenty-two pens where data was available both as pooled data and as sexed data (see Table 4.31, 4.32 and 4.33).



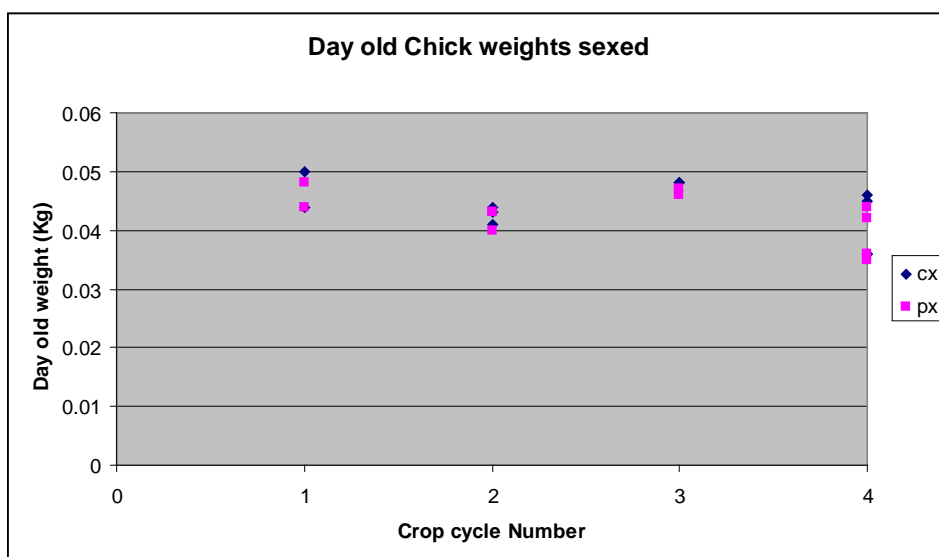
**Figure 4.44: Average weight by house over four crop cycles by house**



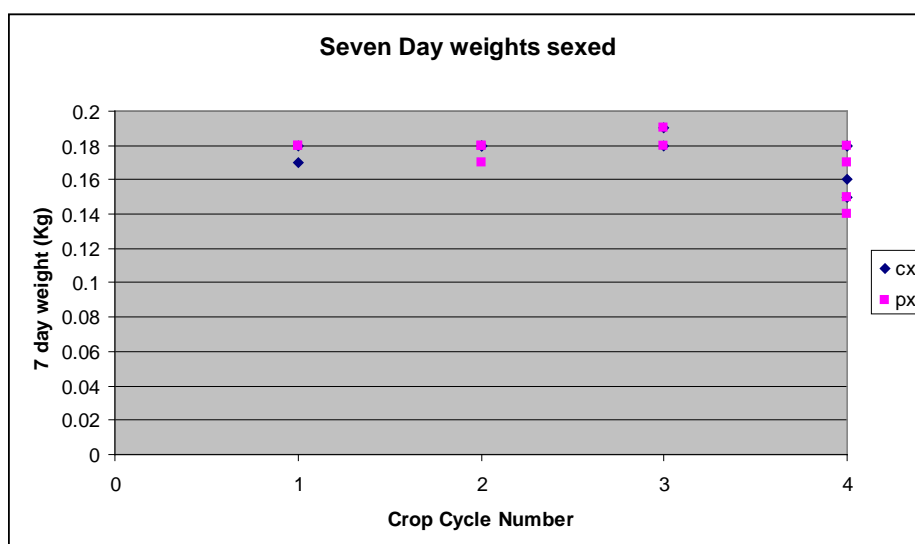
**Figure 4.45: Growth profile over four crop cycles all pens**

The results indicate that for the pooled data there is strong correlation between Day 0 bird weight and bird weight over the subsequent two weeks. The correlation between original chick weight and bird weight at 21 and 28 days is weaker because other factors within the growing environment have a greater influence than day old weight as bird age increases. As would be expected, bird weight at any milestone demonstrates a strong correlation with bird weight seven days before or after at the previous milestone. The same degree of correlation was found from Day 0 to Day 14 when looking at sexed pens as with the pooled data. When the data is assessed by sexed pens there is a marked difference in performance between cockerels and pullets (Figures 4.46, 4.47, 4.48, 4.49 and 4.50). The pullets appear to have performed better than the cockerels during the brooding process with regard to weight gain in the first seven days (Figure 4.47).





**Figure 4.46** Distribution of day old liveweights across pens in a group of sexed birds (n=22)



**Figure 4.47** Distribution of seven day liveweights across pens in a group of sexed birds (n=22)

The results suggest that there is stronger correlation between milestone body weights with pullets compared to cockerels. This could indicate that pullet weight at 28 days is related to day old weight more strongly than cockerel weight at 28 days. Physiological growth factors may be influenced by sex of birds e.g. the influence of sex on the degree of feathering of pullets and cockerels (see 4.5.11). The weight of chicks at hatch is affected by several factors including species and breed, egg nutrient levels, egg environment, egg size, weight loss during the incubation period, weight of the shell and other residues at hatch, shell quality and incubator conditions (Suarez *et al.*, 1997).

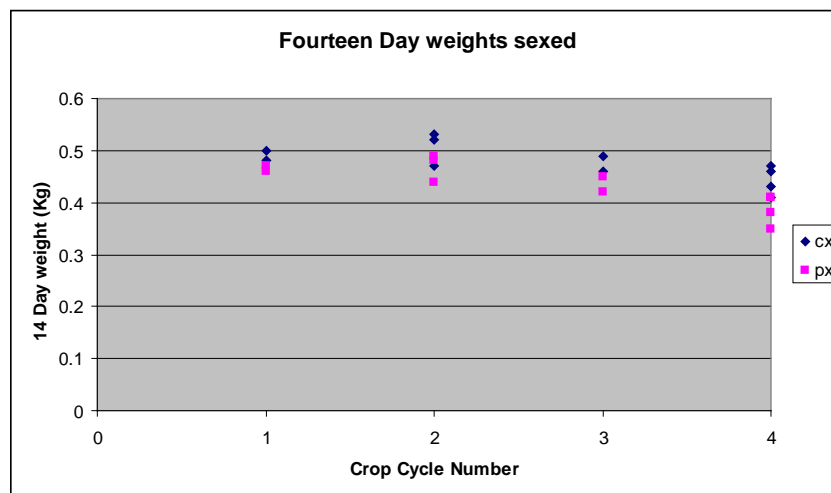


Figure 4.48 Distribution of fourteen day liveweights across pens in a group of sexed birds (n=22)

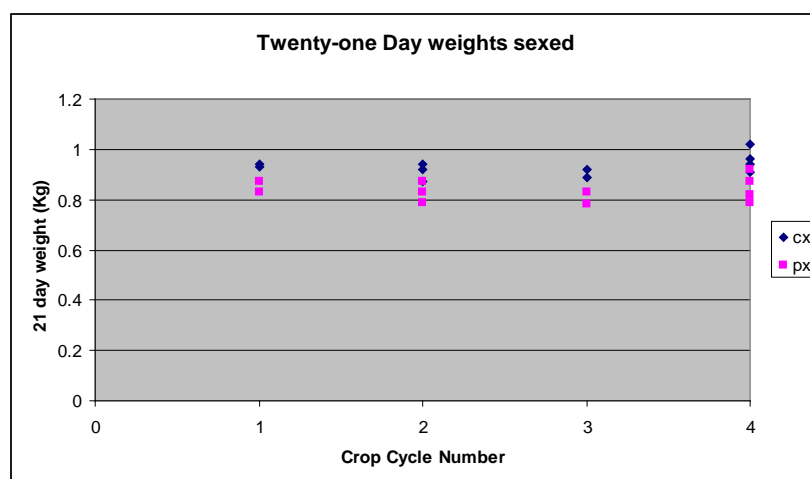


Figure 4.49 Distribution of twenty-one day liveweights across pens in a group of sexed birds (n=22)

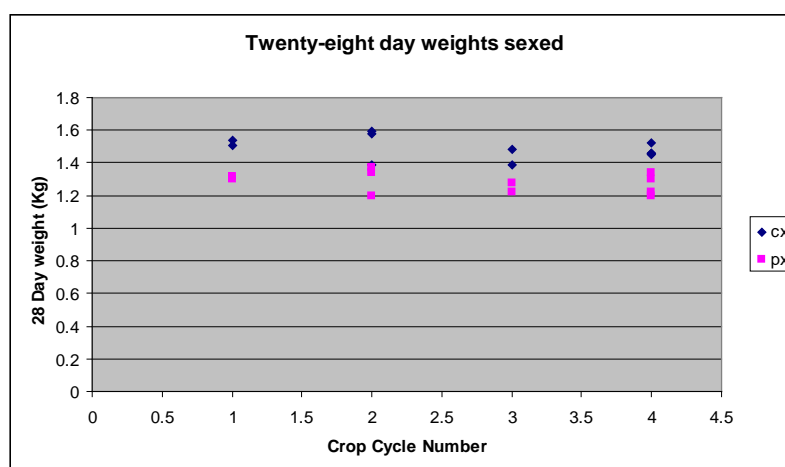


Figure 4.50 Distribution of twenty-eight day liveweights across pens in a group of sexed birds (n=22)

The authors propose that seasonal effects on maternal metabolism, age of hen, egg age also affect chick weight. Egg weight increases with hen age until the end of the laying cycle (Luquetti *et al.*, 2004) and this affects initial chick weight. Robinson *et al.*, (2000) determined that older broiler breeder birds (50 weeks) have larger eggs, heavier chick weight and heavier finished carcass weight compared with chicks from younger breeders (30 weeks).

**Table 4.31: Comparison of individual house performance on the case study site (pooled data)**

	Day 0 Weight (kg)	Day 7 Weight (kg)	Day 14 Weight (kg)	Day 21 Weight (kg)	Day 28 Weight (kg)
Day 0 Weight (kg)		$r = 0.87$ $r^2 = 0.75$	$r = 0.62$ $r^2 = 0.38$	$r = 0.28$ $r^2 = 0.08$	$r = 0.28$ $r^2 = 0.08$
Day 7 Weight (kg)			$r = 0.68$ $r^2 = 0.46$	$r = 0.25$ $r^2 = 0.06$	$r = 0.28$ $r^2 = 0.08$
Day 14 Weight (kg)				$r = 0.46$ $r^2 = 0.21$	$r = 0.71$ $r^2 = 0.50$
Day 21 Weight (kg)					$r = 0.87$ $r^2 = 0.76$

r is statistically significant if it is greater than 0.36 (at 21 DOF) - statistically significant correlation in bold

**Table 4.32: Comparison of individual house performance on the case study site (cockerels - cx)**

	Day 0 Weight (kg)	Day 7 Weight (kg)	Day 14 Weight (kg)	Day 21 Weight (kg)	Day 28 Weight (kg)
Day 0 Weight (kg)		$r = 0.82$ $r^2 = 0.68$	$r = 0.58$ $r^2 = 0.34$	$r = 0.17$ $r^2 = 0.03$	$r = 0.14$ $r^2 = 0.02$
Day 7 Weight (kg)			$r = 0.73$ $r^2 = 0.53$	$r = 0.10$ $r^2 = 0.01$	$r = 0.14$ $r^2 = 0.02$
Day 14 Weight (kg)				$r = 0.10$ $r^2 = 0.01$	$r = 0.66$ $r^2 = 0.43$
Day 21 Weight (kg)					$r = 0.47$ $r^2 = 0.22$

r is statistically significant if it is greater than 0.49736 (at 10 DOF) - statistically significant correlation in bold

Chick quality is also influenced by pre-incubation egg storage and hatchery management (Reis *et al.*, 1997). They also reported that a high proportion of early hatched chicks are female and that dehydration due to the length of time between hatching in the hatcher and removal for separation might produce lighter female chicks. In this study, the average weight of female chicks was 43g (+/- 0.4g) compared with 44g (+/- 0.5g) with male chicks.

**Table 4.33: Comparison of individual house performance on the case study site (pullets - px)**

	Day 0 Weight (kg)	Day 7 Weight (kg)	Day 14 Weight (kg)	Day 21 Weight (kg)	Day 28 Weight (kg)
Day 0 Weight (kg)		$r = 0.82$ $r^2 = 0.86$	$r = 0.69$ $r^2 = 0.48$	$r = 0.36$ $r^2 = 0.13$	$r = 0.54$ $r^2 = 0.29$
Day 7 Weight (kg)			$r = 0.76$ $r^2 = 0.58$	$r = 0.37$ $r^2 = 0.14$	$r = 0.60$ $r^2 = 0.36$
Day 14 Weight (kg)				$r = 0.24$ $r^2 = 0.06$	$r = 0.65$ $r^2 = 0.42$
Day 21 Weight (kg)					$r = 0.79$ $r^2 = 0.63$

r is statistically significant if it is greater than 0.49736 (at 10 DOF) - statistically significant correlation in bold

Gender has a significant effect on chick body weight (Boucher *et al.*, 2006), but the authors found no significant difference in chick body weight due to parent age between 30 and 42 weeks.

However, this does not preclude there being a greater difference with parent age between 30 and 52 weeks. They concluded that initial chick weight was a significant contributor to 42 day weight and an effect of an 8g difference in initial body weight was at least as significant as the effect of gender on body weight at 42 days. It has been suggested (Powley, 2004) that seven day chick weight should be between 140g and 180g. If the growth is equal to or less than 140g it could indicate that there are health and/or environmental factors that are limiting growth. The seven day weight results for the pens described in Tables 4.31 to 4.33 are collated in Table 4.34. They show that other than for one pen all crops had a seven day weight greater than 140g. The factors that could affect seven day weights include incorrect brooding temperature, air humidity or air speed and/or poor access to feed and water either when chicks are placed on when birds transfer from supplementary feed and water to the automated systems. Floor temperature has also been shown to have an impact on seven day weight (Table 4.35: Ross, 2006). The study has assessed the impact of brooding procedures on growth, crop fill, flock uniformity and the coefficient of variation (see section 4.5.10).

**Table 4.34: Seven day weights for sexed pens in growth study**

Crop Cycle	Pen code	7 day weight (kg)
1	h2cx	0.18
1	h2px	0.18
1	h3cx	0.17
1	h3px	0.18
2	h1cx	0.18
2	h1px	0.17
2	h3cx	0.18
2	h3px	0.18
2	h4cx	0.18
2	h4px	0.18
3	h1cx	0.18
3	h1px	0.18
3	h3cx	0.19
3	h3px	0.19
4	h1cx	0.18
4	h1px	0.17
4	h2cx	0.18
4	h2px	0.18
4	h3cx	0.15
4	h3px	0.14
4	h4cx	0.16
4	h4px	0.15

**Table 4.35: Effect of floor temperature on chick performance (Source: Ross, 2006)**

The recommended standard for crop fill is >80% 8 hours after delivery and >95% 24 hours after delivery (Powley, 2004). The data obtained in this study demonstrated that the case study site was complying with crop fill standards in 50% of pens at 8 hours and only 6% at 24 hours. This showed that brooding management procedures on the site could potentially be improved and promotes the value of undertaking crop fill checks to monitor and effectively manage “chick-start”. The crop fill data has been collated (Table 4.36). The results show there was no correlation between day old weight and either 8 hour or 24 hour crop fill for the pooled or the sexed data. There was also no correlation found between crop fill (%) and the variation in cv from day 0 to day 7. Correlation was demonstrated between crop fill at 8 hours and 24 hours in pooled data and with the cockerel data (Figure 4.51), but not with regard to the pullets (Table 4.37). The data has demonstrated a significant difference in chick performance for a day old weight, growth profiles and crop fill especially with regard to bird sex. Further research should be undertaken to analyse these differences in more detail especially to determine if female chick dehydration is a factor and how the differences impact on growth, cv and the degree of flock uniformity.

**Table 4.36: Crop fill data for case study site**

Crop Cycle	Pen Code	Crop fill 8 hrs (%)	Crop fill 24 hrs (%)	Crop fill 8 hrs Compliant (Y/N)	Crop fill 24 hours Compliant (Y/N)
2	h3cx	86	94	Y	N
2	h3px	76	88	N	N
2	h4cx	84	92	Y	N
2	h4px	78	90	N	N
3	h1cx	76	88	N	N
3	h1px	80	96	Y	Y
3	h3cx	90	88	Y	N
3	h3px	84	84	Y	N
4	h1cx	70	70	N	N
4	h1px	78	74	N	N
4	h2cx	74	80	N	N
4	h2px	76	80	N	N
4	h3cx	84	92	Y	N
4	h3px	80	90	Y	N
4	h4cx	84	90	Y	N
4	h4px	84	92	Y	N

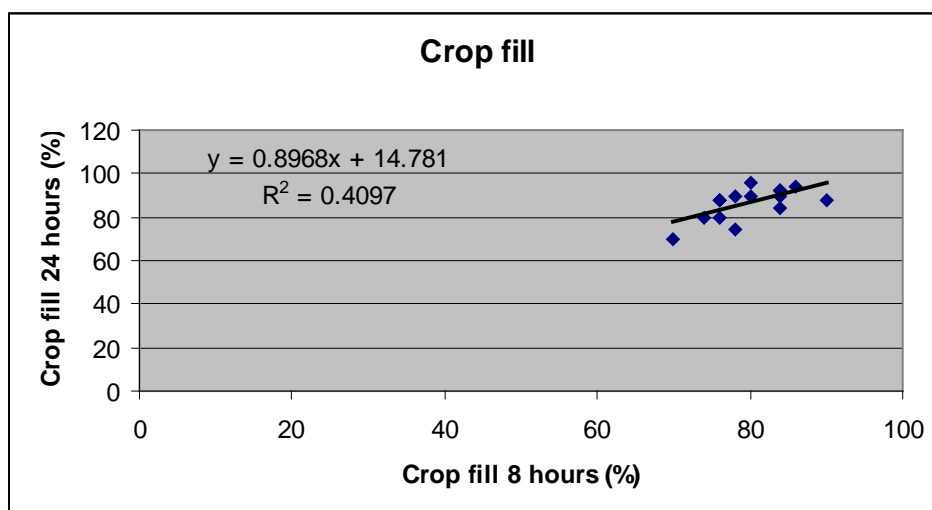


Figure 4.51 Correlation between 8 hour and 24 hour crop fill pens in a group of sexed birds

Table 4.37: Correlation between crop fill and Day 0 weight

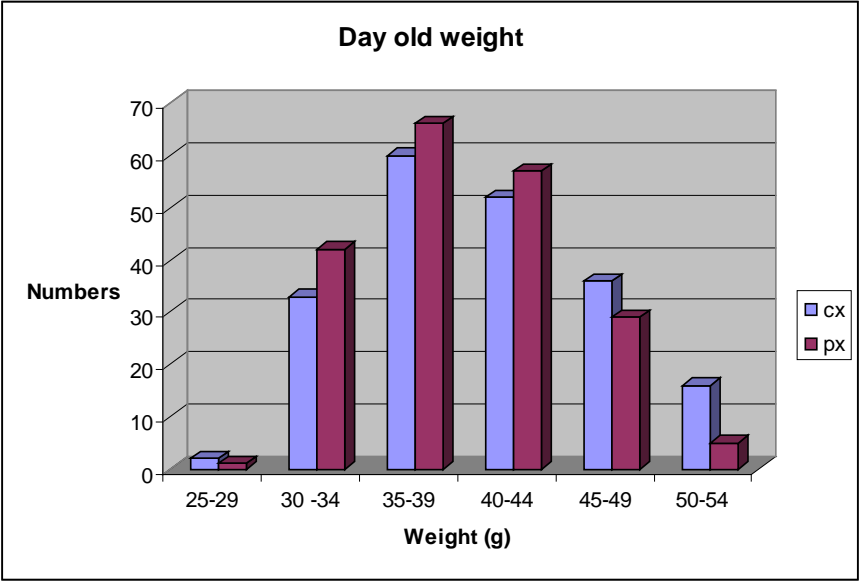
Parameter	Crop fill (24 hours) – pooled data	Crop fill (24 hours) – cx data	Crop fill (24 hours) – px data
Crop fill (8 hours)	$r = 0.64$ $r^2 = 0.41$	$r = 0.82$ $r^2 = 0.67$	$r = 0.33$ $r^2 = 0.11$

$r$  is statistically significant if it is greater than 0.582 (at 7 DOF) - statistically significant correlation in bold

#### 4.5.10 Flock uniformity and coefficient of variation

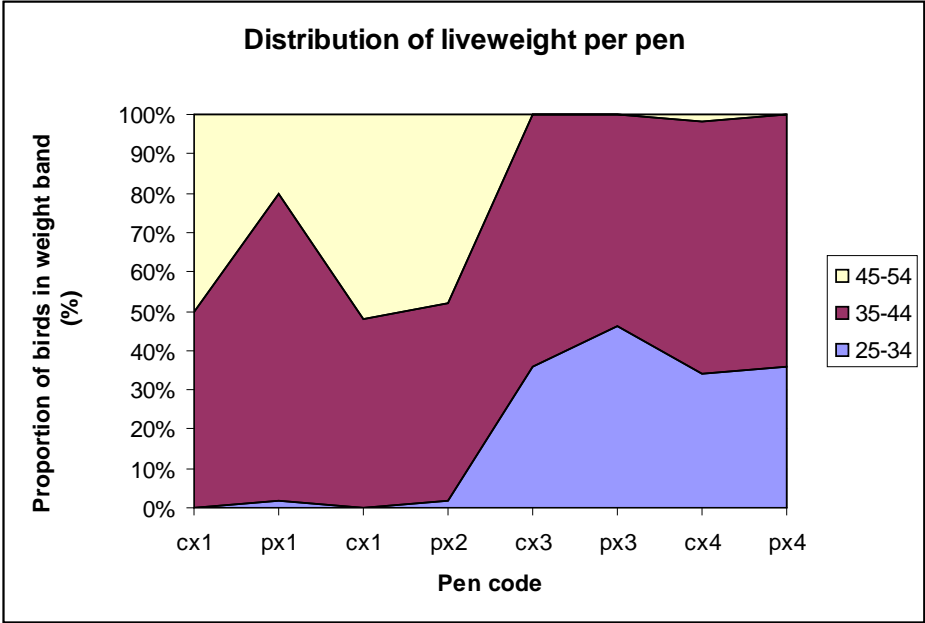
One of the key performance drivers for broiler growing is producing as many birds as possible to the required weight. Birds which are too small will not meet the customer specification and birds which are too large will lead to “giveaway” when sold as portioned products thus reducing integrator (processor) margin. A flock of broilers will tend to follow a normal distribution (Ross, 2006). As hatched pens as opposed to sexed pens will be more variable and therefore CV analysis will give less reliable results as it would not be practical in the commercial situation to weigh equal numbers of male and female birds from a mixed sex house (Ross, 2006). The variability of a population is described by the coefficient of variation (CV %). CV is the standard deviation of the flock expressed as a percentage of the mean thus the greater the variability the higher the CV. The term “% uniformity” is sometimes used which is termed the percentage of the flock within 10% of the mean. Ross (2006) have described flocks which have a “good” variability as having a cv of approximately 8% (or 80% uniformity); “average” flocks as would have a CV of 10% (or 70% uniformity) and poor flocks as above 12% (or less than 60% uniformity). With good management the CV% at 7 days should be no higher than the CV% at hatch (Ross, 2006). For one crop cycle on the case study site the cv was monitored for day-old and seven day chicks. The

day old weight data for the eight sexed pens in the four houses has been pooled (Figure 4.52) to demonstrate the distribution of live-weights.



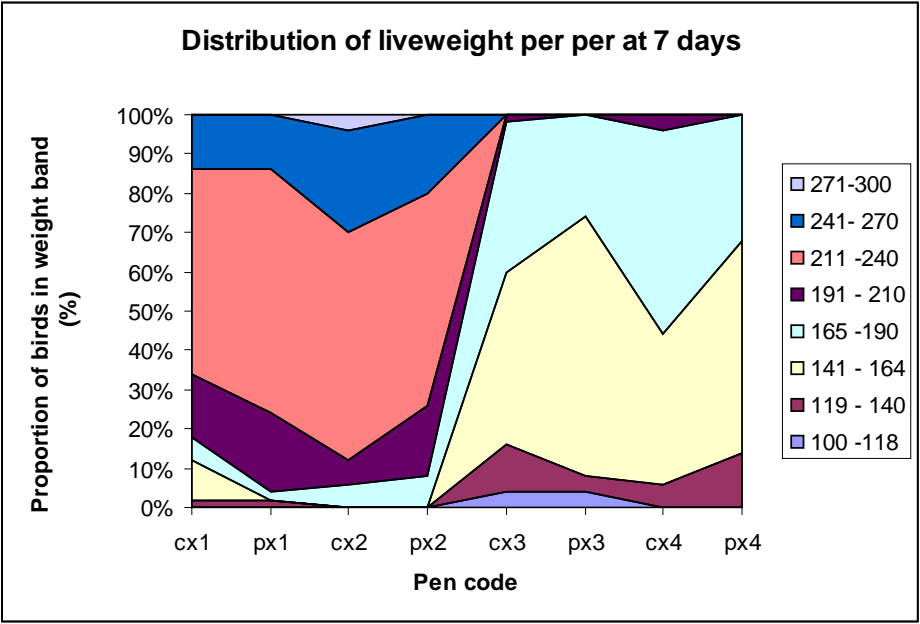
**Figure 4.52: Distribution of liveweights across eight pens in a group of sexed birds (pooled data)**

The range of chick size ( $n = 400$ ) was 35 – 53 g for cockerels and 26 – 54 g for pullets. This suggested a greater variability in pullet weights. The graph shows the differing distribution profile between male (cx) and female (px) birds. The data was then analysed per pen and shows that houses 3 and 4 had a much higher proportion of smaller chicks (Figure 4.53).



**Figure 4.53: Distribution of day-old liveweights across eight pens in a group of sexed birds (pen data)**

Ross (2006) suggests that seven day weight should be between 4.5 and 5 times higher than day old weight. On the case study site bird weight has been measured at seven days (Figure 4.54) and the results show a variance between the weight in Houses 1 and 2 and Houses 3 and 4. The top three weight bands were only found in Houses 1 and 2. The variance in CV between Day 0 and Day 7 has been calculated and compared for four crops.



**Figure 4.54: Distribution of seven day liveweights across eight pens in a group of sexed birds (pen data)**

CV calculations can only be undertaken for pens with a single sex, single flock code so pens where there was more than one flock code could not be analysed. Ross (2006) has defined the performance standards for the change in CV over the brooding period (Days 0 – 7) in order to differentiate between poor, average and good performance (Table 4.38).

**Table 4.38: Indication of performance from variation in CV (Source: Ross, 2006)**



Four crop cycles were assessed for the change in CV from day old chicks to seven day weights (Table 4.39). 58% of the day old chicks were within the 7 – 9% CV range (n = 26) with 19% below 7% CV and 23% above 9% CV. None of the seven day old chicks were within the 7 – 9% CV range (n = 26) with 27% below 7% CV and 73% above 9% CV. This showed that there was a trend towards the CV increasing during the brooding period.

**Table 4.39: CV performance on case study site**

Crop		1	2	3	4
House	Sex	CV Day 0 7 – 9 %	CV Day 0 7 – 9 %	CV Day 0 7 – 9 %	CV Day 0 7 – 9 %
1	Cx		10.2	8.9	7.9
	Px		6.2	7.2	7.9
2	Cx	9.4		8.9	9.2
	Px	9.7		7.2	10
3	Cx	8.2	6.6	6.4	8.7
	Px	9.0	7.8	9.0	6.4
4	Cx		9.8	6.4	11.7
	Px		7.3	9.0	7.5
House	Sex	CV Day 7	CV Day 7	CV Day 7	CV Day 7
1	Cx		10.9	9.9	14.6
	Px		12.4	9.2	11.9
2	Cx	10.4		8.7	11.0
	Px	8.3		12.8	9.1
3	Cx	10.1	7.1	10.5	12.6
	Px	13.4	13.5	11.0	10.1
4	Cx		9.3	7.1	10.5
	Px		7.1	7.7	8.3
House	Sex	Difference in CV	Difference in CV	Difference in CV	Difference in CV
1	Cx		0.7	1.0	6.7
	Px		6.2	2.0	4.0
2	Cx	1.0		0.2	1.8
	Px	1.4		5.6	0.9
3	Cx	1.9	0.5	4.1	3.9
	Px	4.4	5.7	2.0	3.7
4	Cx		0.5	0.7	1.2
	Px		0.2	3.1	0.8

Analysis of the variation in CV showed that only 62% of pens had a performance that was deemed either good or excellent (Table 4.40). The CV, together with crop fill, is a useful tool in determining the effectiveness of brooding management and any actions which need to be taken to improve performance and should form part of any poultry supply chain QA model. The use of electronic scales in poultry houses should aid collection of CV data. Computer programmes could also be developed to further enhance this management tool to give timely indication of chick

progress during brooding when corrective action can still be implemented if required. These latter KPI offer the ability to monitor broilers during the crop cycle and are important tools which the grower needs to use to ensure that birds grow uniformly and meet processing standards. This is especially critical when seeking to meet the whole bird market. The indicators are worthy of future study in order to refine the QA model.

**Table 4.40: Indication of performance from variation in CV (Source: Ross, 2006)**

#### **4.5.11 Factory rejects**

Factory performance lag indicators such as dead on arrivals (%) or reject levels (%) have been traditionally used in the poultry industry to determine carcass quality and food safety criteria (see Manning *et al.*, 2006c). All birds undergo post-mortem inspection in the processing plants (MHS, 2006). The MHS Manual for Official Controls puts forward the following conditions as indications of poor welfare on catching, during transport or at slaughter: broken bones, bruising, badly bled carcasses or breast blisters. The manual states that septicaemia and/or toxemia represented 14.75% of total conditions rejections in 2004. The reject levels for this condition over the five crop cycles analysed in the water consumption study (see 4.5.7) was found to be 8.9% which was less than the figure suggested in the literature. The DOA data did not afford detailed analysis. The mean DOA was 0.10% with an SD of 0.06 where  $n = 29$  crops.

Factory rejections can be for a variety of welfare, quality or food safety criteria the most common being septicaemia, skin lesions, cellulites, ascities, edema, emaciation, bruising, pericarditis or perihepatitis. Bird health issues can give rise to rejections. The incidence of contact dermatitis has already been discussed in this thesis. Skin diseases are one of the main reasons for condemnation of carcasses (Bergmann *et al.*, 1995) and one of the key issues which challenges the industry is the level of rejects caused by cellulitis. In Canada, in 1986 cellulitis represented 0.05%

of the reject rate, however by 1996 the reject levels had increased to 0.56% and was the highest cause of carcase condemnation in Canada (Boulianne, 2006). In the US, the average carcase condemnation was found to be 0.16% but it has been reported that figures for individual flocks can run as high at 6% (Summers, 2006). Summers also described a positive correlation between average bird weight and reject levels. He also reports that male and as-hatched flocks were 7.9 and 3.9 times more likely to experience cellulitis than female flocks, respectively.

Cellulitis is caused by *E. coli* infection and is only detectable at slaughter (Boulianne, 2006), once the carcase has been scalded and plucked. It is due to plaques of pus underneath the skin with associated inflammation. Cellulitis arises due to a scratch to the skin, very often on the abdomen or thigh, which then becomes infected. Risk factors include management procedures that promote jostling amongst birds when scratches can occur, higher stocking density, and flightiness in the flock which can increase damage Boulianne (2006). Poor quality litter, with higher levels of bacterial contamination, will also promote bacterial infection of any scratches that occur. The following management protocols (Summers, 2006) have been suggested to prevent or control cellulitis:

- Quality of feathering;
- Bird aggression;
- Use of growth promoter (with a suggested link with increased cellulitis)
- Farm and hatchery hygiene;
- Use of wood shavings as the preferred litter material; and
- Stocking density;

A slow-feathering bird will have less protection against such scratches. Boulianne (2006) argues that research has identified that birds kept at higher temperatures between days 17 and 35 have an increased incidence of cellulitis. This could be due to the fact that this will promote later feathering thus leaving birds with vulnerable skin areas. The degree of feathering may therefore play a part in the incidence of cellulitis. Specific genes are associated with the variance of feathering rates between male and female chickens. Research has also been undertaken investigating the relationship between sex-linked feathering and growth rate; disease resistance and commercial performance traits (Lilburn, 2006) Bird uniformity, the formation of feathers and

skin strength is also influenced by both protein intake and bird age, especially in an as-hatched programme (Lilburn, 2006). It has been determined that for a male broiler bird weighing 2 kg at slaughter, a slow feathering bird which synthesises 16g less feather protein will produce 8g more edible meat protein and 46g more carcass meat than a fast feathering one (SAC, 2006), of which 55% of the extra meat is breast meat. The decrease in feather cover will also reduce the carcass fat content. The other benefit is easier chick sexing and the production of extra breast meat is therefore a market driver towards growing birds that feather at a slower rate. Further research needs to be undertaken to determine if the potential impact on welfare of slower feathering, and the economic loss of increased carcass condemnation is off-set by the improved performance especially in the whole bird rather than the deboned market.

The mean factory reject levels for all crops (n = 61) was 0.99% (SD 0.53, IQR = 0.68 – 1.12). The data from the benchmarking group has been analysed for Group 1 (mean reject level = 1.09%, SD = 0.44, IQR = 0.80 – 1.29) and Group 2 (mean reject level = 0.85%, SD = 0.19, IQR 0.64 – 0.84). The results complied with the requirements of the ACP standard (see Table 4.41). The correlation was determined for all sites which provided annual data (n = 8) between reject levels and a number of factors. There was no correlation between reject levels and crop length or bird residence period; seven day mortality, or water consumption (L/bird/cycle) or (L/m<sup>2</sup>/wk). This implied that the factors affecting reject levels could be site specific or crop specific and there was no underlying correlation on a given site or within groups of sites. On a site basis, the case study site demonstrated (Table 4.22) that there was a strong positive correlation in crop cycle 4 between foot pad dermatitis (r = 0.91), reject levels (r = 0.88) and a strong negative correlation with growth (r = -0.76) and water consumption in terms of L/m<sup>2</sup> when comparing individual poultry houses and further research needs to be undertaken in this area.

**Table 4.41: Reject and carcass quality standards**

	<b>ACP (2006)</b>	<b>EU Broiler Welfare Directive</b>
Total Mortality (%)	5	1 plus (0.06 x slaughter age)
PMI rejects (%)	1.5	-
Hockburn (%)	15	-
Foot pad dermatitis	-	50 points (analysis of 200 birds)
DOA (%)	-	<0.5

The negative correlation with growth could be an indication of an increase in water consumption due to enteritis. This then led to a physiological challenge to the birds that caused a reduction in growth. Data for reject levels was available per house on that cycle but was not suitable for detail analysis.

#### **4.5.12 Conclusion**

The literature review papers and working papers and the research model assessment which has been undertaken in this chapter have identified the benefits of utilising a QA model in order to drive compliance with legislative and market requirements. This chapter has reviewed traditional performance indicators and the key IPPC performance indicators to determine whether they can also be used to provide information on animal health and welfare and food safety criteria. The study has also analysed industry accepted methods for monitoring brooding and growth patterns and examined whether they can be used to monitor health and welfare and correlate with factory reject levels. The use of KPI within a QA model should identify the factors which impact on supply chain performance and the ability at each stage to meet supply chain standards. Once such standards have been defined quality plans should be put in place to identify when and the frequency at which these factors should be assessed; the method for assessment; the criteria that need to be met and the actions that will deliver legislative compliance. Chapter Five draws together the final conclusions of the study.

## **CHAPTER 5 – CONCLUSIONS**

### **5.1 Introduction**

The PhD study has firstly defined the current position with regard to existing and evolving UK and EU legislation, world trade agreements and institutions, global trade in chicken meat and market QA standards in a series of peer-reviewed published papers and working papers. The following areas of legislation have been reviewed: food safety; environmental; conservation and biodiversity; animal welfare; health and safety and social legislation. The development of global food supply chains can be a key driver in the harmonisation of international legislation, product and private assurance standards. Compliance with legislation and retailer requirements has been a key market driver in the development of private assurance standards. The key objectives of the research were to:

- Examine current assurance schemes within the integrated poultry meat supply chain (see 5.2);
- Examine the influence of regulation and external market drivers within the integrated poultry meat supply chain (see 5.3 - 5.5);
- Develop and test a QA model for the poultry meat supply chain with a view to both baseline and higher level standards including the development of a business benchmarking system (see 5.6 – 5.7); and
- Assess the ability of the QA model to deliver regulatory and policy compliance whilst meeting varied business and market needs for an internationally traded product (see 5.8 - 5.12).

The conclusions reached as a result of this study are discussed in this chapter and in the individual papers in the appendix.

### **5.2 Private Assurance Standards**

The current status of the UK poultry industry with regard to the development of QA systems against the changing regulatory policy, market and consumer environment has been investigated in this study. Current private QA schemes verify through routine independent inspections that organisations are meeting certain prescribed standards (Manning and Baines, 2004a). These standards are set by the QA scheme, vary between schemes and generally address food safety,

traceability, animal health and welfare and environmental protection. Thus poultry meat can be marketed on the basis that the birds have been produced to those standards. These however are extrinsic rather than intrinsic quality standards and will not in themselves form a business model which drives supply chain efficiency and business improvement, nor ensure that key consumer criteria such as product consistency, price or availability are met. The standards can largely only implement controls that the market can afford and there is always a commercial viewpoint to consider when analysing market based QA standards. Current poultry farm assurance standards have been “benchmarked” using comparative analysis in order to identify similarities and differences. The conclusions drawn are that terms such as “baseline” and “higher level” do not relate to intrinsic product characteristics such as flavour and meat texture, but to extrinsic production standards (Appendix 9). Higher level schemes often address extrinsic factors within the scheme such as bird welfare or environmental management whilst failing to formalise standards for legislative requirements such as food safety and personnel health and safety which is addressed by many baseline standards. It would suggest therefore that the current classifications of “baseline” and “higher level” schemes are rather simplistic and potentially confusing to consumers.

The research has also demonstrated that producers are primarily complying with poultry farm assurance standards in order to maintain market access (Manning *et al.*, 2007c). The poultry producers involved in the study indicated that to date they have not generally perceived other organisational or financial benefits as a result of compliance with the farm assurance standard other than continuing to supply their existing retail customers. Against this backdrop of UK supply chain assurance the thesis has discussed different approaches to QA and the development of business models (Manning *et al.*, 2006a). A QA model which drives both legislative and customer compliance and has the capacity to improve organisational performance needs to be based on two elements. First it requires a pre-requisite programme which defines Good Manufacturing Practice (GMP)/Good Agricultural Practice (GAP), as appropriate to the stage in the supply chain; and secondly a benchmarking protocol which measures performance quantitatively against key criteria. The implementation of such a model should assist an organisation to implement an ongoing management process which will drive business excellence by measuring performance,

implementing change to drive improvement and identifying ways to be more competitive in the market place whilst meeting customer and legislative requirements.

### **5.3 Food safety and the deliberate contamination of the food supply chain**

The contamination of a food source whether accidental or deliberate can have far reaching consequences. This is especially so in a society where increasingly responsibility for the safety of the food that is eaten is entrusted in food processors, the retail sector and food service. This trend has developed in the manufacturing environment where globally there has been a change from responsibility with government inspectors to responsibility being with individual food businesses (Manning and Baines, 2004a). The development of private assurance schemes has led to third party certification at all levels of the supply chain. These audits are usually on an annual basis and as a result are largely based on visual inspection and documentation. They can only verify that systems have been developed to assure quality and food safety and that there is sufficient evidence to demonstrate that the organisation is, or alternatively is not, compliant with those systems. The private assurance standards have not been developed to ensure complete control of food safety hazards. The trend from third-party inspection based compliance to third party certification will require a food business to demonstrate the effectiveness of a QMS. This may give a greater level of assurance especially if food businesses have set food safety as well as quality objectives and measure their performance. However, food continues to be grown and processed outside any specific assurance standards and without particular attention to formalised food safety systems. Due to the lack of traceability systems with these non-assured products, it also means that any potential investigation of a food poisoning outbreak caused by this food source is limited.

Effective risk communication is one of the biggest issues the industry faces. Food safety needs to be communicated in a relevant way to all sectors of the supply chain and most specifically to consumers so that they can make well-informed decisions when purchasing food. Private assurance schemes have been developed to meet the needs of individual partners in the food supply chain, but have not been developed to ensure whole chain regulatory compliance. Therefore individual businesses need to develop their food safety management systems not only to meet the needs of the private assurance schemes but also to ensure they have addressed all



legislative requirements where they exceed those defined in the scheme. The HACCP management tool is not a zero risk system it can only work towards minimising risk through effective assessment of potential food safety hazards and the means for their control. Furthermore, a food safety management plan is only as effective as the skills and knowledge of the team developing and implementing it. A weak analysis of the potential food safety hazards will lead to ineffective food safety management. HACCP is only truly effective when it is suitable to the process, reflects the realistic food safety hazards associated with the product, identifies suitable controls and a monitoring programme which has then been validated to ensure the critical limits determined will deliver safe food.

It has been argued in this thesis that a single action of deliberate food contamination in one location can have significant impact on a regional, national and even international basis (Manning *et al.*, 2005). This is especially so as the globalisation and consolidation of food procurement increases. Indeed, it is possible to contaminate food in a country where controls are limited and cause major human health consequences and economic disruption in another. Food supply chains increasingly work on short lead times so the impact on the general public of such an incident would be immediate, especially if measures are not in place to switch to an alternative source of supply or indeed where there is no alternative source. National and regional government should develop a strategy that ensures an integrated, rapid response to incidents in order to minimise the human, animal welfare and economic impact of such an action. The control of plant and animal health issues, deliberate contamination of the water supply or the food supply chain on a regional or even national scale also requires a co-ordinated approach often across international borders. This approach needs to include:

- a combined strategy agreed between government and industry;
- adequate resources available for investigation;
- preparedness planning which is routinely tested to ensure effectiveness; and
- Developing surveillance systems to collate data and subsequent analysis to determine any trends.

Within the UK, response mechanisms need to include the co-ordination of governmental departments such as laboratory and food inspection services, state veterinary and human health

professionals in order to ensure a measured and pro-active response to a suspected or actual incident within the food supply chain

#### **5.4 Ethical issues**

Legislation defines governmental policy but it does not define what is “good” or “right” and this is the role of ethics. In order to have ethical reasoning embedded in food policy either at governmental or organisational level, policy makers must be able to understand and evaluate moral arguments, be fair-minded and make well reasoned decisions. Consumers need to trust that both policy makers and those manufacturing and supplying food make decisions and provide information which is accessible, accurate and affords reasoned choice when purchasing food products. Policy makers must consider that perceived risk may be based on value based as well as scientific based judgement, be fair-minded and make well reasoned decisions, otherwise they will be unable to maintain consumer confidence in their respective policies and strategies. Public concerns with issues including animal welfare and environmental management and stewardship have required organisations within the food supply chain to formally demonstrate their commitment to ethical issues. This has led to the development of corporate social responsibility strategies and the use of ethical risk assessment models. However in order for the ethical supply chain model to be effective and sustainable, it actually requires “society” to pay for what is “good” or “fair” where this has a commercial implication (Manning *et al.*, 2006b).

#### **5.5 Global supply chains**

Increasing globalisation of the poultry meat supply chain has led to consolidation and the evolution of TNC whether by vertical or horizontal integration and the development of business clusters (Manning and Baines, 2004b and paper ten). There are significant benefits for the supply chain and for the consumer (see Chapter 2). This study reviewed the key factors which have led to the globalisation of the poultry supply chain and the impact of these changes. The financial data provided by retailers and food processors which has been examined in this study has demonstrated that organisations have had to address performance and rationalise and refocus their activities. This has led some processing/manufacturing organisations to move away from commodity products and seek to add value and thus increase margin. In the UK, the increasing cost of compliance with environmental legislation including IPPC and animal by-product disposal

has meant that there is a legislative driver for the industry to move to the commodity whole bird and portion market rather than manufacturing deboned meat products. The cost of labour in the UK when compared with other poultry producing areas such as Brazil and Thailand has also driven this trend. This research therefore defined the organisational performance context in which the research model is functioning.

## **5.6 Benchmarking the food supply chain**

This study has reviewed the background to benchmarking and how benchmarking can be used to identify performance indicators. The Curry Report (PC, 2002) focused on the economic benefits of benchmarking, but it has been argued in this study that to be effective, benchmarking must not focus solely on financial analysis. Benchmarking must also drive the identification and implementation of best practice and knowledge transfer between those involved (paper nine). The market driver for supply chain integration is a need to improve both supply chain profitability and competitive position, however the benefits of integration are not necessarily equally shared at all stages of the supply chain. Supply chain integration can lead to the concentration of control of distribution channels by a small number of organisations (Power, 2005). One strategic response for those supplying into the chain is collaboration at a horizontal level (Barratt, 2004). It has been demonstrated in other industries just how effective benchmarking can be in delivering a lean, efficient supply chain. However, we need to consider how “agile” the poultry supply chain needs to be (paper nine) so that it can respond rapidly to stakeholders and the market, both in terms of specified intrinsic and extrinsic product requirements and ensuring continuity and consistency of supply.

The integration of stages and the cyclical nature of broiler production along with the long lead times (see 3.2) mean that the primary sector cannot implement rapid change especially within the confines of a pushed production system. Horizontal private benchmarking systems allow for confidentiality whilst providing a mechanism for driving business improvement as demonstrated in this study. Public benchmarking where the results are freely available to all members of the supply chain can lead to the powerful members of the chain, such as processors or retailers putting pressure on primary producers to provide all the cost benefits to them. This mechanism means

that the primary producer does not receive the financial benefit of their improved performance; their only benefit is to continue to supply the market with reduced revenue. Benchmarking approaches have evolved from initial cost-focused comparative analysis to process orientated benchmarking. Indeed it can be argued that if not effectively implemented, benchmarking techniques can focus too much on historic data rather than identifying and implementing current best practice. Effective supply chain benchmarking is more than a comparative analysis of cost structure. It requires a detailed understanding of the processes undertaken in order to determine the ideas and information that needs to be shared both vertically and horizontally in the chain which in turn will deliver compliance with stakeholder requirements and drive continuous improvement.

Following development of the research model, competitive benchmarking has been undertaken with a group of individual broiler growers (paper nine). This process has been used as a management tool to:

- identify current and developing best practices; and
- Analyse production and supply chain costs and identify ways to reduce them further whilst identifying key supply chain and consumer requirements and ensuring that they are consistently met.

This study has shown the same that KPI can be used to also assess food safety, animal welfare and business performance criteria. This study has developed a dual approach. Firstly, the study has developed a benchmarking protocol to assist in the comparative analysis of individual sites or organisations. Secondly, the study has assessed which criteria should be incorporated into a supply chain QA approach to drive “real-time” process development. This dual approach is an important mechanism to drive supply chain efficiency and the level of compliance with process requirements.

### **5.7 Development of key performance indicators**

Many researchers have sought to develop computerised growth models for broiler production (paper nine). The research model developed as a result of this study was primarily developed for broiler growers supplying the whole bird/portions market however it has application to all sectors.

The research model addresses growth within the portfolio of criteria which have been analysed (see 4.5.9).

#### **5.7.1 Food safety performance indicators**

As previously stated, ensuring compliance with food safety legislation and market requirements is one of the key issues facing the poultry meat industry. The purpose of this research has been to analyse how a pre-requisite programme (PRP) and key performance indicators (KPI) for food safety can be developed in the poultry meat supply chain. Effective food safety management systems in primary production are critical to supplying food which is safe and wholesome. In order to manage food safety effectively, as has already been discussed, measurable indicators of performance should be developed (Manning *et al.*, 2006c). These will provide data on the suitability of the food for sale, the effectiveness of the food safety management system and any potential areas of weakness which in turn will drive continuous improvement. The study has shown that many factors can interact in poultry meat production to affect bird health, welfare and performance, carcase quality and the financial sustainability of the supply chain. The factors concerned can have influence either independently or cumulatively.

#### **5.7.2 Animal welfare performance indicators**

A key business driver to the development of performance indicators is the impact of bird health and welfare on financial performance and supply chain viability. For welfare assessment to be quantitative rather than subjective, welfare indicators need to be determined and objectively measured. Welfare performance indicators must be readily communicated to all stakeholders and understood by all those in the supply chain (Manning *et al.*, 2007a) and ongoing performance must be monitored.

#### **5.7.3 Environmental impact performance indicators**

Seeking to comply with environmental legislation such as IPPC, the EU Waste Incineration legislation and Animal By-products Regulations, whilst remaining globally competitive is one of the major issues facing broiler production in the UK. The research assessed how the environmental impact of broiler production can be quantitatively measured. Case study data was collected from a commercial broiler sites and then compared with industry benchmarking figures. The results

indicate general compliance with benchmarking figures but concluded that to benchmark the environmental performance of different broiler production systems we may need to relate environmental performance indicators to floor area (m<sup>2</sup>) or kilograms (kg) of liveweight produced rather than nominal bird places. This theme has been developed further in the research model.

## **5.8 The research model**

The development and the methodology of testing the research model for the poultry meat supply chain was discussed in Chapter Three. The model has been tested in the field in order to determine whether it can:

- Deliver legislative compliance;
- Deliver production standards that are sustainable in the current industry price structure;
- Quantify business performance;
- Enable organisations to develop internal mechanisms for driving continuous improvement to meet key financial and quality objectives;
- Deliver transparency of standards so that consumers can make a reasoned judgment between the range of food items available when purchasing poultry meat products;
- Differentiate between performance indicators which provide discrete financial data only; provide discrete data on bird, site or equipment performance; provide continuous data which is not limited to a specific crop cycle; provide historical data; and can be used to aid the management of the site to influence performance within the crop cycle.

Supporting graphical analysis of the data can be found in Appendix 7.

## **5.9 Traditional performance indicators**

### **5.9.1 Total mortality**

The results of the study comply with published literature (see 4.2.1). The performance indicator can differentiate between good, average and poor performers. The study demonstrated there was a statistically significant difference between actual mortality and data adjusted for bird residence period. Therefore it is important to take into account average bird age and/or bird residence period when analysing total mortality and to adjust by a factor so that sites on different growing programmes can be compared (Heier *et al.*, 2002). Total mortality provides historic discrete data

which is limited to a specific crop cycle, but can demonstrate business performance and animal welfare. It is however a crude measure and it cannot be reversed.

### **5.9.2 Seven day mortality**

The mean seven day mortality for all sites was 0.76% which was well below the published figures (4.2.2). The use of IQR can differentiate between individual site performances. No correlation was shown between seven day and total or adjusted total mortality in commercial production. This historic performance indicator provides discrete data on chick supply and site performance and is limited to a specific crop cycle but can be skewed unless the impact of therapeutic medication is considered.

### **5.9.3 Leg cull mortality**

The overall results of the study for leg culls complied with the work undertaken by Dawkins *et al.*, (2004). The data showed there was a statistically significant difference in the percentage of leg culls in birds over and under 42 days of age. The performance indicators can differentiate between good, average and poor performers and a correlation was shown between leg culls and total mortality i.e. the higher the leg culls the higher the total mortality, which would have been expected. This indicator provides discrete bird and site performance, but is historic in nature. Therefore the mortality indicators described as well as fourteen day mortality, sudden mortality and dead on arrivals whilst being crude indicators will provide an indication of bird health and welfare and site performance.

### **5.9.4 FCR, EPEF and average weight**

The results indicate that although the groups had very similar results neither were meeting the predicted standards for bird age. Figures 7.12 and 7.13 demonstrated that there was a variation between sites for FCR and EPEF. The IQR has been effective at differentiating between site performances. The parameter provides historic discrete data which is limited to a specific crop cycle, but can demonstrate business performance and animal welfare.

#### **5.9.5 Birdplace efficiency**

There was a strong negative correlation shown between birdplace efficiency and average weight i.e. the higher the average weight, the lower the birdplace efficiency. The influence of stocking density was analysed and the results suggested that birdplace efficiency was driven by placement and depletion stocking density (birds/m<sup>2</sup>), the later having the greater correlation. IQR was used to determine site performance for bird place efficiency. The parameter provides historic discrete data which is limited to a specific crop cycle, and is used primarily to quantify business performance.

#### **5.9.6 Feed usage and feed to water consumption ratio**

There was a strong positive correlation between feed usage and average weight by site and by crop. New indicators, namely FLR and WLR, were developed and this quantified the difference in performance between the sites with actual feed/water consumption compared to the expected consumption. Further research needs to be undertaken with a larger data set to determine whether the linear regression formulae are a useful tool within the QA model. Feed consumption to water consumption ratio was determined. The ratio was found to vary between summer and winter crop cycles. This result complies with the work of Lacey (2002) and by the authors in Georgia (2001). This ratio can be used to differentiate between standard and non-standard site performance and demonstrates that two indicators can be used together to gain a further understanding of performance on the site and/or during the crop cycle. This data will provide discrete data on bird and site performance but is limited to a specific crop cycle and is historical data. Further research should be undertaken to determine if this ratio is a useful intra-crop as well as inter-crop indicator.

#### **5.9.7 Crop length and fallow period**

The results of the study for crop length and fallow period could differentiate between group performance and site performance. The results as would be expected demonstrate that there is a strong negative correlation between bird place efficiency and crop length as previously described in 5.9.5. The performance indicators can define financial performance for a crop cycle and are retrospective.



### **5.9.8 Conclusion**

The results for each performance indicator were collated in Table 4.1 by site and by individual crop. The traditional indicators demonstrated a strong difference in terms of average and IQR between group 1 and group 2 in terms of group performance. The results suggested that other than for seven day mortality and FCR there is a statistically significant difference between the two production systems. Therefore this study would propose the two production systems should not be considered as equivalent when undertaking comparative performance or financial benchmarking and that separate benchmarking standards should be adopted.

## **5.10 Additional QA performance indicators**

### **5.10.1 Total water consumption**

There are many factors which influence water consumption and these were described in sections 4.3.1 and 4.5.1. Data on water consumption complied with the IPPC BREF (2003) standard. Individual site performance was analysed and showed a variance between individual sites and crops and between production systems when considering water consumption in terms of L/bird. It is a useful indicator however when compared with feed usage (see 5.9.6). The limitation of total water consumption as an indicator for assessing bird performance and welfare is that it is historic; covers all houses on the site rather than individual houses or pens and implies that all the water that enters the house is consumed. Nevertheless it is a powerful indicator of environmental performance and bird health which can differentiate between good, average and poor performance.

### **5.10.2 Water used for terminal hygiene**

Results from the study complied with the IPPC BREF (2003) benchmark. This is a useful indicator of environmental performance and it will also aid broiler growers to determine the practices undertaken during terminal hygiene. This has implications too for both bird health and welfare and food safety.

### **5.10.3 Energy usage**

Annual electricity usage figures from three sites complied with the Defra (2004) benchmarking figure of 250 – 300 kWh/1000 birds and there was no statistically significant difference for electricity usage between the two groups in kWh/1000 birds. The study showed that there is a differentiation in electricity usage performance when considering kWh/1000 birds (due to the variance in placement density and crop length) compared with kWh/kg liveweight. It could be argued that kWh/kg liveweight is the preferred indicator because it is more closely linked to ventilation rates. The average annual gas usage was analysed for the five sites that provided data and indicated that the level of site gas usage may be a multi-factorial depending on bird residence period, different growing temperature profiles or the external air temperature during brooding either increasing or decreasing gas usage.

Total energy usage was analysed for six sites over four crops. The average usage per site complied with the published figures of Peirson, (1999). There was a strong positive correlation between total energy usage (kWh/bird or kWh/kg liveweight) and average residency period. The energy performance indicators were able to distinguish between good, average and poor performers. This study suggested that energy usage benchmarking should be introduced into comparative benchmarking analysis in order to drive energy usage improvements and potential cost savings. It is important to consider the impact of stocking density and growing programme when determining energy efficiency. Energy usage benchmarking has been examined and it has demonstrated that the performance indicators assessed show a large variance between sites. It is important to use the most appropriate indicator when comparing different production systems. Energy usage benchmarking should be introduced into comparative benchmarking analysis in order to drive energy usage improvements and potential cost savings.

### **5.10.4. Conclusion**

The benchmarking data discussed so far in this chapter has been historic. This study has not only researched traditional and additional QA models indicators but also sought to analyse current and

develop novel, real-time indicators which can influence management practices during the crop cycle (see 5.12).

### **5.11 Comparative financial analysis**

The financial data collated during this benchmarking study was found to be comparative with the work undertaken by Sheppard and Edge (2006). The financial performance results from this study suggested the average broiler grower is producing at an average profit margin of 1.3%, but even lower if they have a disease challenge, or a business with high capital repayments, labour costs or rental payments.

### **5.12 Performance indicators which can drive real-time analysis**

#### **5.12.1 Factors affecting water consumption and contact dermatitis**

The literature review has demonstrated that water consumption can be affected by a number of interacting parameters including the chemical composition and the level of dissolved solids in the drinking water and feed dietary factors. Environmental factors such as air temperature and velocity will also have an effect. Defra (PB1739, 2006) determine that a number of these self-same factors affect the condition of poultry litter. It has also been suggested that these factors have a cumulative effect. The cumulative effect after considering the effect of an all-vegetarian diet, removal of growth promoters could be a 20% increase in faecal production. If there are additional additive factors such as a disease challenge, mineral constituents in the drinking water or type of drinker system this will increase the level of faecal production still further. Three parameters were used to measure water consumption and it has been established that the better indicator to compare different production systems was litres/bird/day rather than L/bird/cycle because this was influenced by bird residence period. The parameter  $L/m^2$  is a useful indicator in determining the amount of water per area of litter; and will also determine the impact of stocking density. Each site has been shown to have its own water consumption finger-print for internal benchmarking purposes. These factors need to be considered further using a larger data set in a future refinement of the model

When considering total water consumption, it could be assumed that the daily consumption profile is uniform for all houses and all crops, it has been shown that this is not the case. The research has therefore investigated whether there is a correlation (rather than seeking to prove a causal link) between total or daily water consumption and factors such as growth, reject levels and contact dermatitis. The results indicate that there was a strong correlation on the case study site between total water consumption in L/m<sup>2</sup> of floor area and levels of foot pad dermatitis and bird rejects at the factory and between total water consumption in L/bird/cycle and foot pad dermatitis. The study also demonstrated that water consumption was a beneficial “headline” indicator in determining individual house performance, as it identified a house which was a consistent “bad-performer”. The study also showed that using site averages could mask poor performance in an individual house or pen. The study also demonstrated that there was a correlation between the levels of foot pad dermatitis and water consumption on specific days in the crop cycle. This result is worthy of further investigation.

#### **5.12.2 Leg health**

Leg health can be monitored using indicators such as % leg culls or gait scoring. Kestin et al., (1992) suggested that leg weakness in commercial broilers was related to rapid juvenile growth rate and that there was a strong correlation between leg weakness and growth rate. This research study has shown similar results with a strong correlation between body weight and leg culls (Table 4.25).

#### **5.12.3 Growth rate and crop fill**

Although the average growth rate by house demonstrates close correlation, there was large variation between the different sexed pens on the case study site. The results indicated that for the all data there was strong correlation between Day 0 bird weight and bird weight over the subsequent two weeks. The correlation between original chick weight and bird weight became weaker for pooled data and for cockerels as age increased. Pullets and cockerels also differed in the weight gain in the first seven days. The results suggest that there is stronger correlation between milestone body weights with pullets compared to cockerels i.e. that pullet weight at 28 days relate more strongly to day old weight than equivalent cockerel weight. The factors affecting

initial chick weight have been discussed. The study has also assessed the impact of brooding procedures on growth, crop fill, flock uniformity and the coefficient of variation. Further research should be undertaken to analyse the variances identified between pullets and cockerels in more detail especially the rate of feathering and how they impact on growth, CV and the degree of crop uniformity and factory reject levels.

#### **5.12.4 Flock uniformity and coefficient of variation**

The case study site demonstrated that 58% of the day old chicks were within the expected uniformity range and there was a trend towards the CV increasing during the brooding period. Analysis of the variation in CV showed that only 62% of pens had a performance that was good or excellent. It was determined that the coefficient of variation, together with crop fill, was a useful tool in determining the effectiveness of brooding management and any actions which need to be taken to improve performance.

#### **5.12.5 Reject levels**

Reject levels have been discussed due to contact dermatitis and cellulitis. Effective management of these issues needs to be assured in order that bird welfare is effectively managed and also because they impact on financial performance. The data has demonstrated that there was an intra-crop correlation between water consumption in L/m<sup>2</sup> and reject levels, foot pad dermatitis and growth. Further work needs to be undertaken in this area to determine if this parameter can be used to monitor environmental considerations which cause factory rejections and seek to reduce the incidence.

### **5.13 General Conclusions**

These latter described key performance indicators offer the ability to monitor broilers during the crop cycle and are important tools which the grower needs to use to ensure that birds grow uniformly and meet processing standards. This is especially critical when seeking to meet the whole bird market. The indicators are worthy of future study in order to refine the QA model. The EU Scientific Committee for Animal Health and Welfare (SCAHAW, 2000) concluded that for an "adequate" assessment of welfare, although single indicators can show that welfare is poor, a

wide range of indicators must be used. The novel performance indicators developed as a result of the study were: the adjusted mortality figure (%), bird residence period (days), feed usage linear regression factor (FLR), water linear regression (WLR), energy usage (kWh/kg liveweight), water consumption (in terms of L/bird/day and L/m<sup>2</sup>). These performance indicators, either individually or in combination, have been able to provide information on bird health and welfare and performance which has not been available to date through using more traditional indicators. The study has also identified that factors which affect rejection levels are worthy of further consideration in order to improve bird welfare and supply chain performance.

One of the aims of this research study has been to add to the existing portfolio of indicators which are available to poultry growers to be able to influence and modify performance during the crop cycle. The QA model has essentially been developed in order that:

- It can be easily communicated to poultry growers;
- It utilises as many traditional indicators as possible which are familiar to the growers;
- Performance can be readily identified; and
- The statistical analysis involved in the QA model can be undertaken by growers using a standard computer spreadsheet.

This study has shown that a QA model is capable of providing a structure within which the poultry meat supply chain can operate. The legislative and performance requirements have been translated into quantifiable performance indicators which can be used to measure supply chain performance. This can aid differentiation of products at the point of consumption. The benchmarking group has been able to demonstrate compliance with legislative and market requirements for the criteria studied.

The greatest threat to the poultry meat supply industry both in terms of animal health and welfare and organisational and supply chain viability is the spread of zoonotic disease, such as avian influenza. As has been shown with the advent of H5N1 globally, especially where there is a resultant loss of consumer confidence, this can immediately impact on the viability of the industry.

Managing risk in the poultry supply chain has been discussed (Manning and Baines, 2004b and paper ten). Risk management requires a multidisciplinary approach from the management team and integrated risk management through the supply chain will lead to improved organisational sustainability. Risks can be categorised into distinct groups (ICAEW, 2002) but complete elimination of risk or reduction to an acceptable level is not always possible especially in a livestock supply chain. The development of risk management strategies, including investor risk assessment, in the context of globalisation should ensure improved organisational management of areas such as maximising cash availability, reducing the impact of currency changes, interest rates or flow of investment and managing price variation and its impact on margin. However key performance indicators need to be developed to act as an early warning mechanism to identify when risk is not being sufficiently managed and before control is lost.

The effectiveness and viability of the poultry meat supply chain will be determined by the interaction of the governance structure in how it shares the risks and rewards of the supply chain among participants (Gray and Boehlje, 2005). They further argue that if primary producers are risk adverse this can lead to a slower adoption of new technologies and business practice. Poultry integrators have either chosen the route of vertical integration where they can effectively manage more of the risk or else have delegated that risk to other supply chain partners. It is important for the viability of the poultry meat supply chain that the potential vulnerabilities that exist are fully understood. Key vulnerabilities within the UK industry include the threat of notifiable disease, the increasing cost of legislative compliance, the agility of the supply chain when adapting to change, and the financial performance of individual players within the supply chain.

In order to manage these viabilities effectively and minimise their impact, those operating in the poultry meat supply chain must be able to understand the degree of dependence and interdependence within the chain; research market decisions before they are implemented to determine the impact on bird health, welfare and performance because what is deemed a positive outcome may be significantly outweighed by a resultant negative one; benchmark activities to ensure that key criteria are being met and have fully developed and tested contingency plans and emergency response plans in the event that they are required.

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# Development of a Quality Assurance Model for Poultry Meat Production.

Appendices

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## **APPENDICES**

Appendix 1: Causal diagram for a poultry carving enterprise (Minegishi and Thiel, 2000).

Appendix 2: Supply chain questionnaire.

Appendix 3 : Pre-requisite programme.

Appendix 4 : QA model.

Appendix 5 : Benchmarking spreadsheet.

Appendix 6 : Benchmarking spreadsheet v2.

Appendix 7 : Graphical analysis of data.

Appendix 8: Legislation and international food standards.

Appendix 9: Quality assurance: a study of the poultry meat supply chain.

## Appendix 7 – Analysis of Benchmarking Data

Figure 7.1: Average total mortality by site compared to average residence period

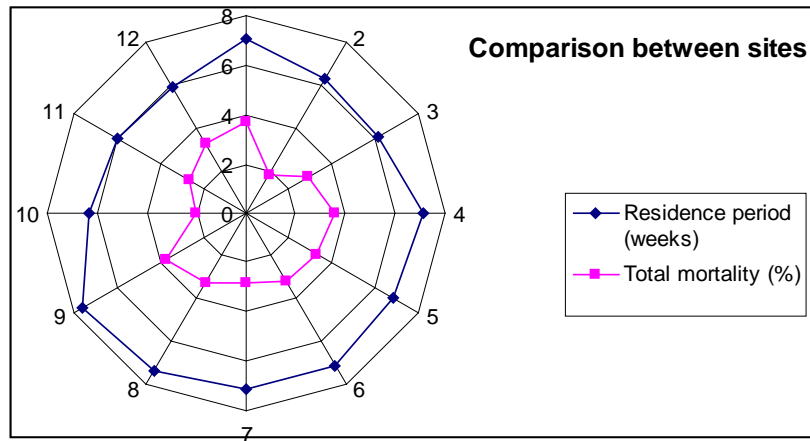


Figure 7.2: Average site 7 day mortality

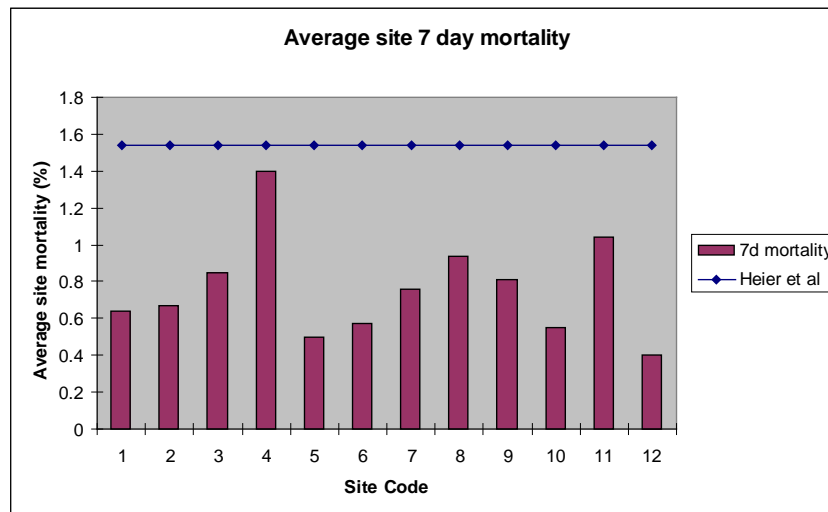
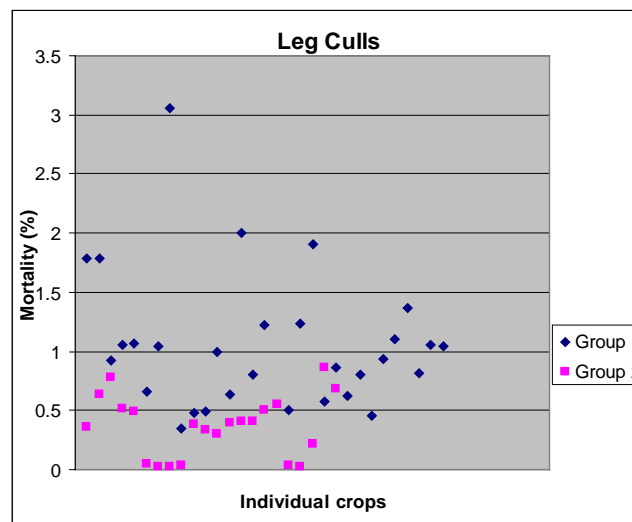


Figure 7.3: Comparison of leg culls for individual crops



## Appendix 7 – Analysis of Benchmarking Data

Figure 7.4: Average total mortality, 7 day mortality and leg culls by site (Bar chart)

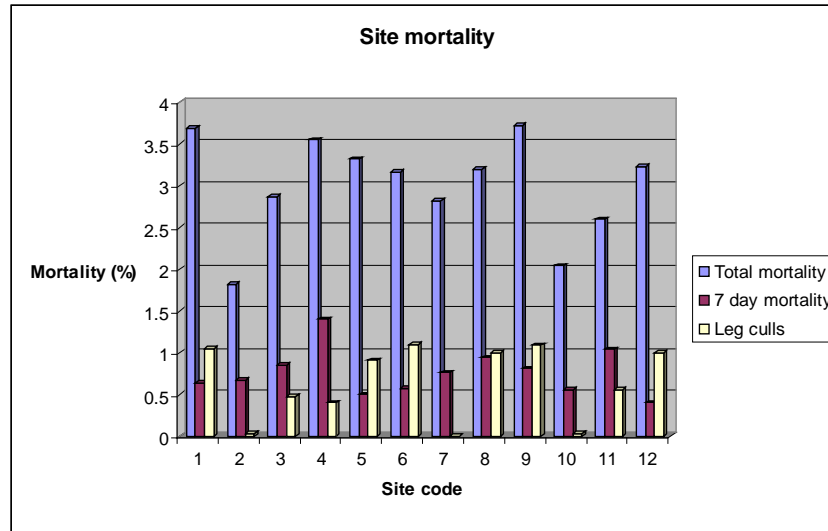


Figure 7.5: Average total mortality, 7 day mortality and leg culls by site (Spider diagram)

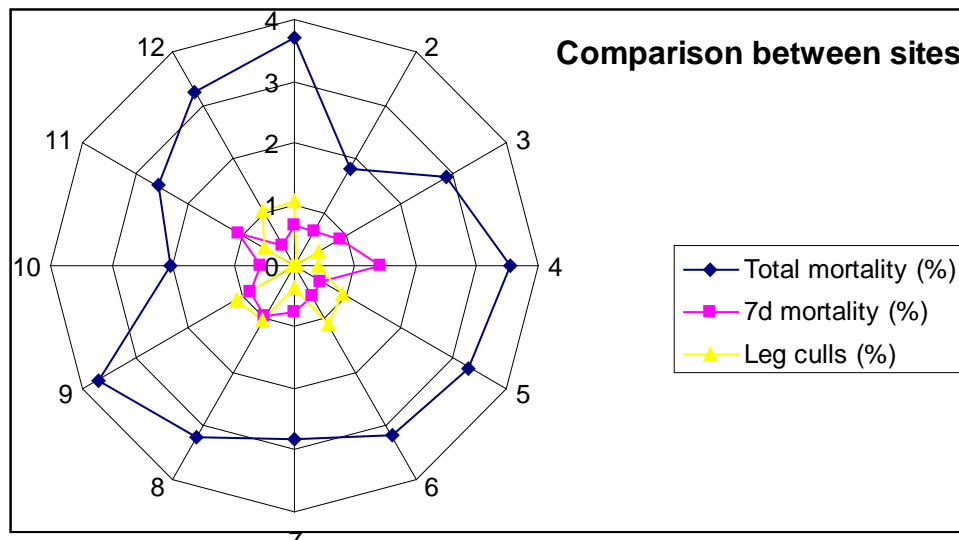
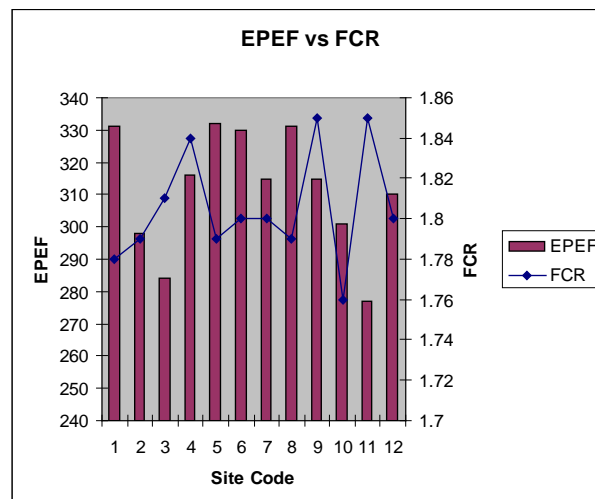


Figure 7.6: Relationship between EPEF vs FCR per site



## Appendix 7 – Analysis of Benchmarking Data

Figure 7.7: Average weight by group for each crop

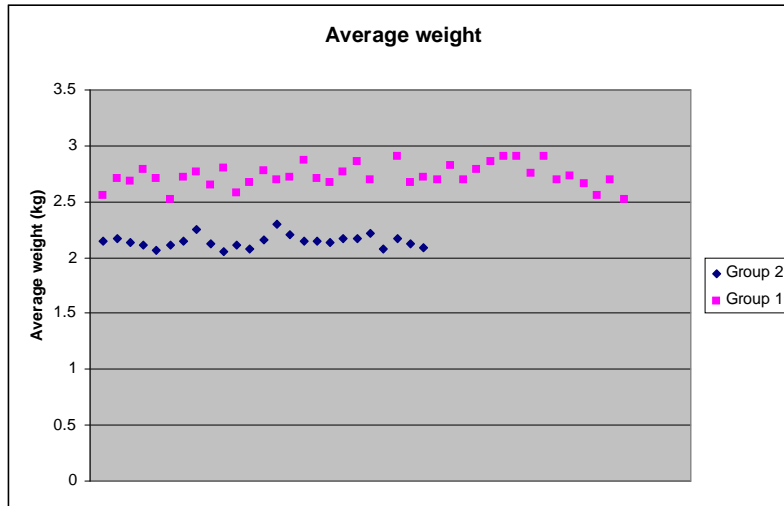


Figure 7.8: Birdplace efficiency by crop

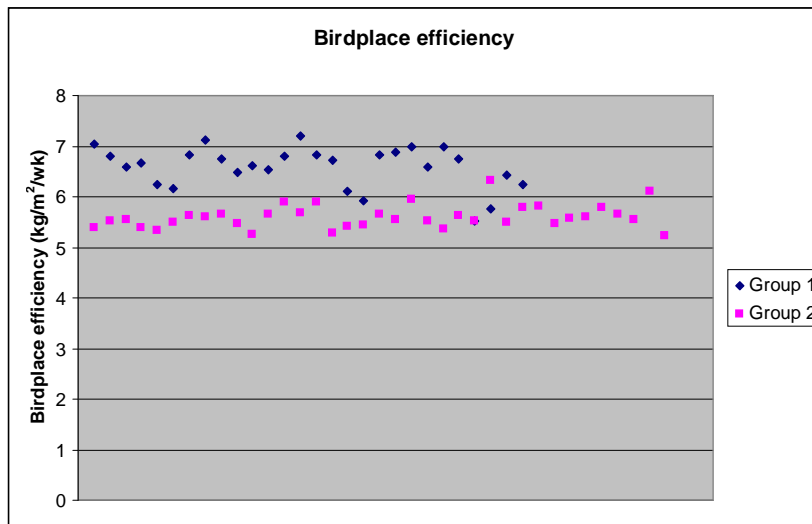
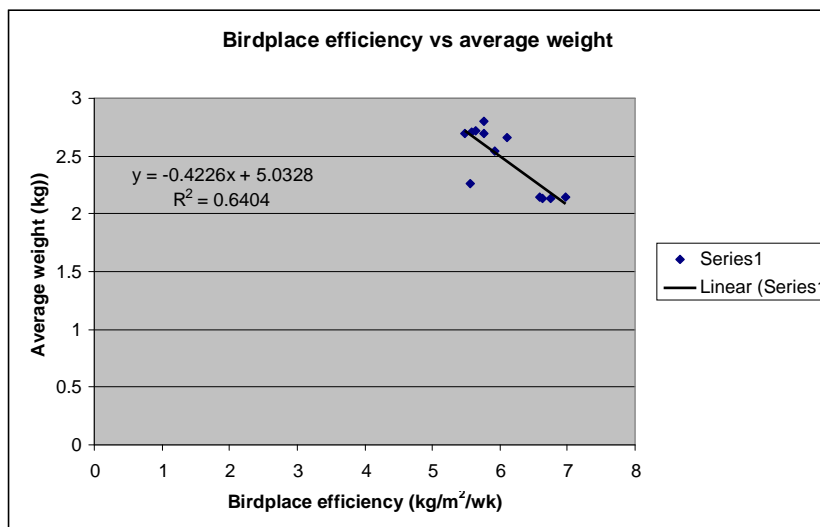


Figure 7.9: Birdplace efficiency vs average weight by site



## Appendix 7 – Analysis of Benchmarking Data

Figure 7.10: Birdplace efficiency vs average weight by crop

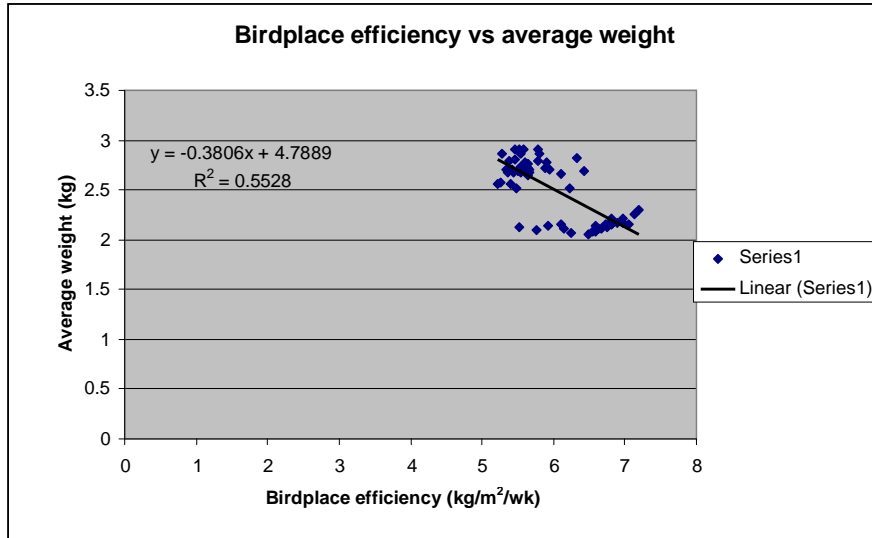


Figure 7.11: Birdplace efficiency vs total mortality by site

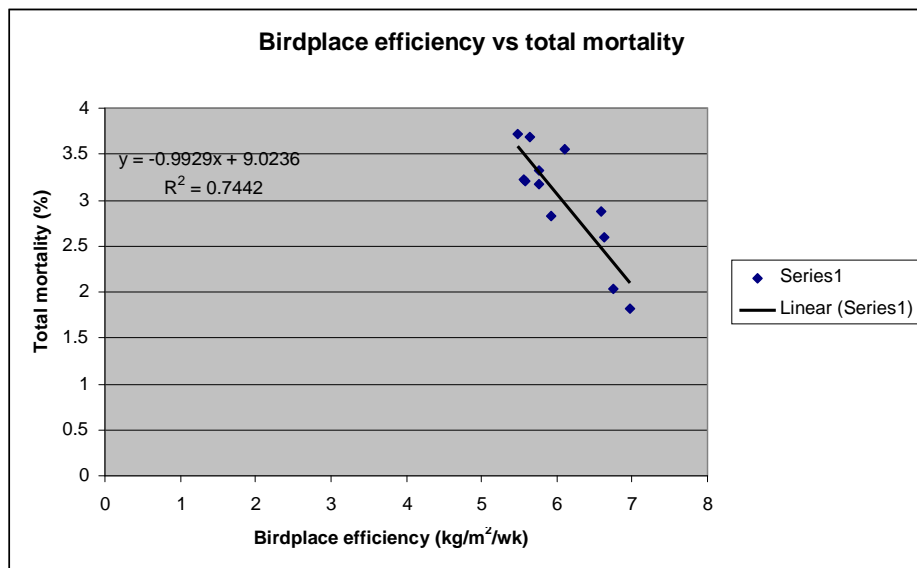
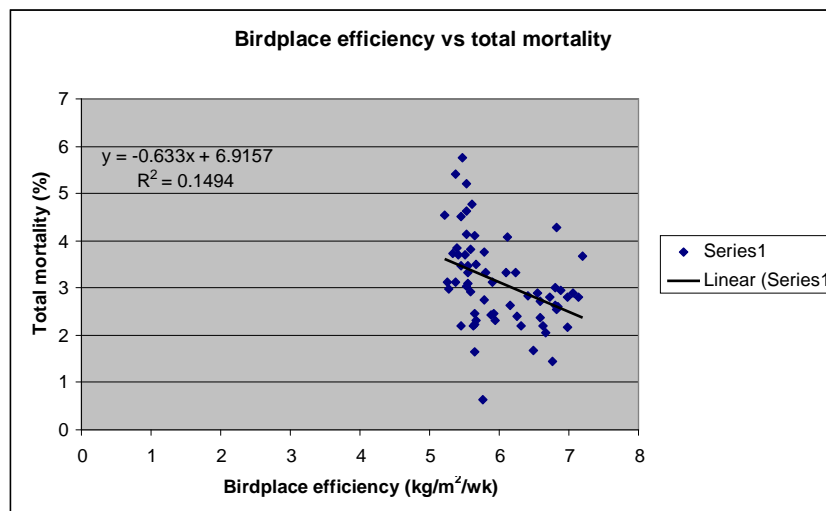


Figure 7.12: Birdplace efficiency vs total mortality by crop



## Appendix 7 – Analysis of Benchmarking Data

Figure 7.13: Feed usage and its relationship to average weight by site

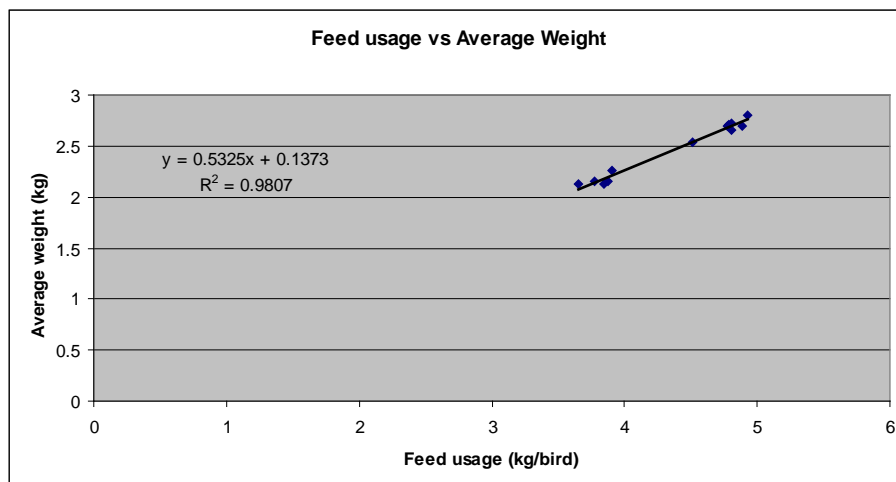


Figure 7.14: Feed usage and its relationship to average weight by crop

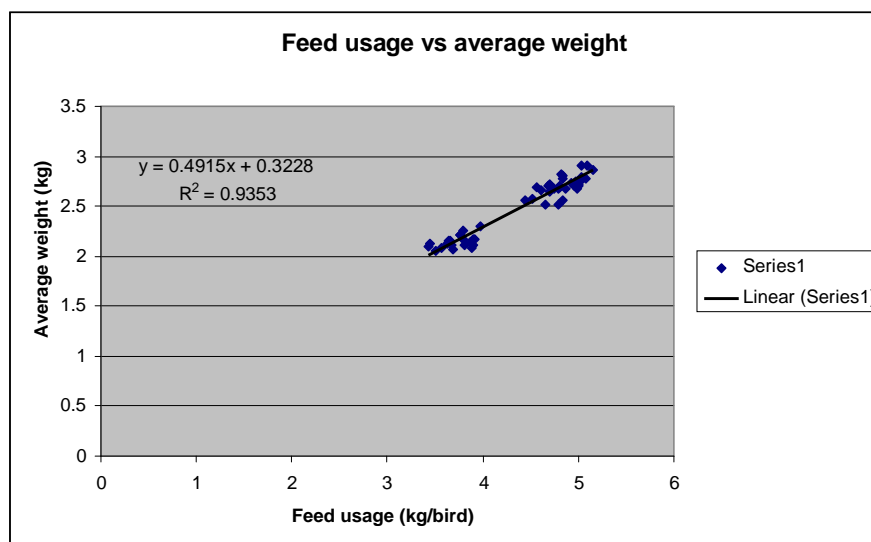
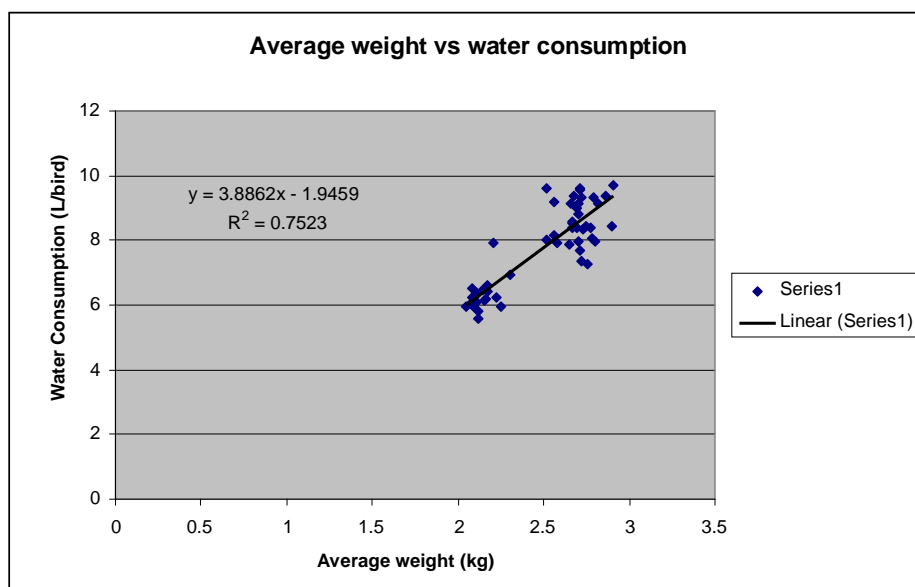


Figure 7.15: Average weight and its relationship to water consumption





## Appendix 7 – Analysis of Benchmarking Data

Figure 7.16: Annual Water: Feed ratio by site

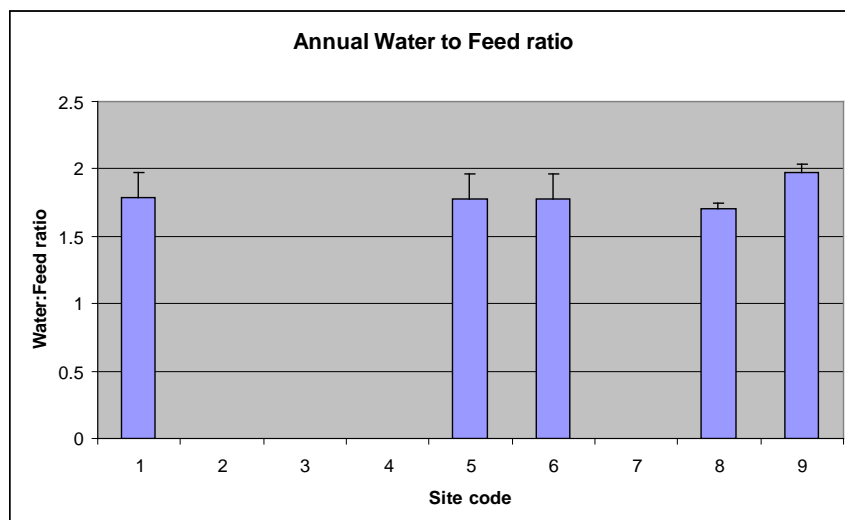


Figure 7.17: Water: Feed ratio by crop cycle

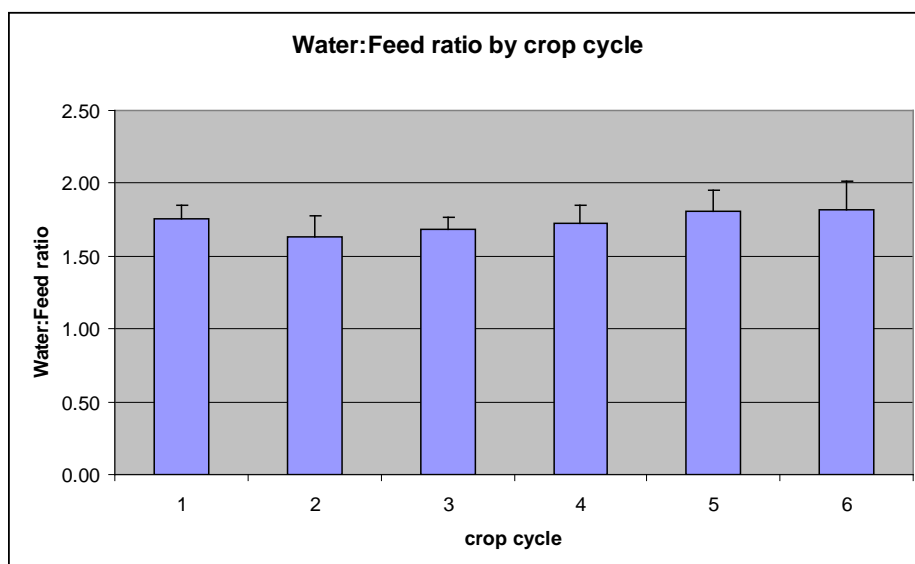
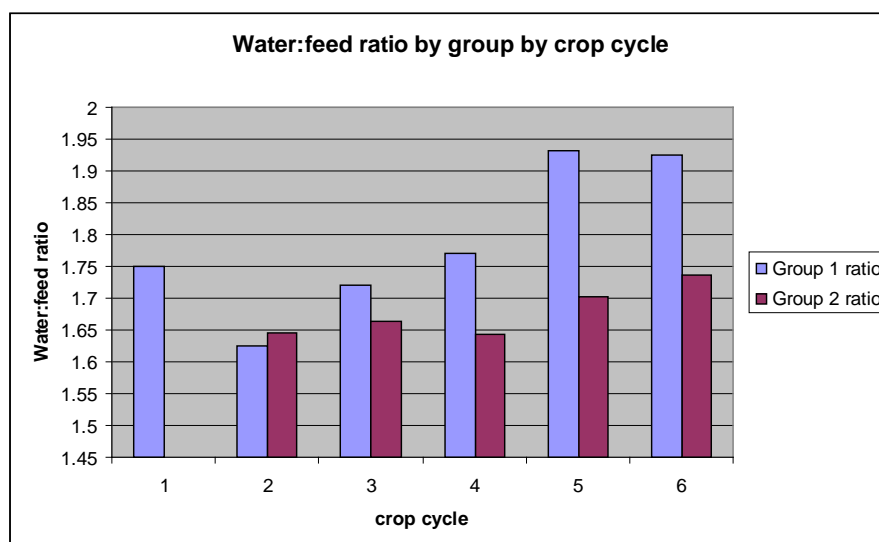


Figure 7.18: Water: Feed ratio by group by crop cycle



## Appendix 7 – Analysis of Benchmarking Data

Figure 7.19: Water: Feed ratio by site by crop cycle Group 1

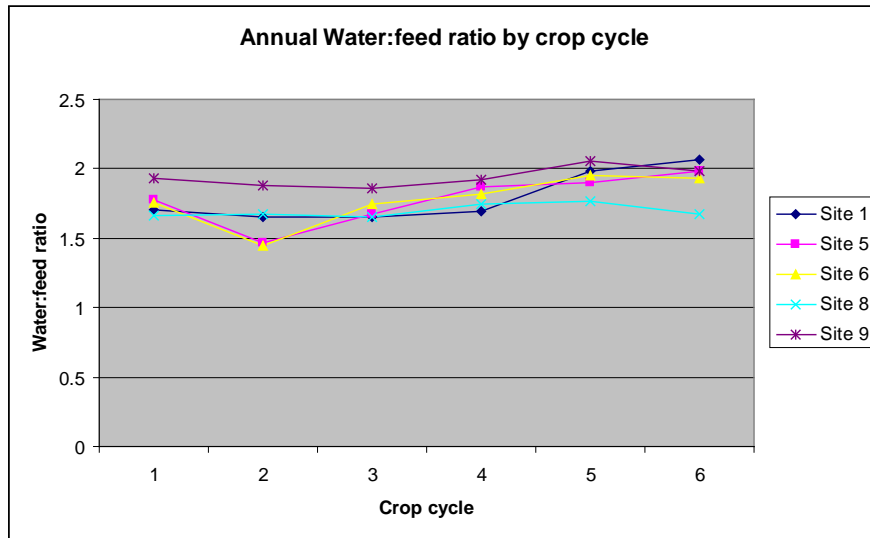


Figure 7.20: Birdplace efficiency versus crop length

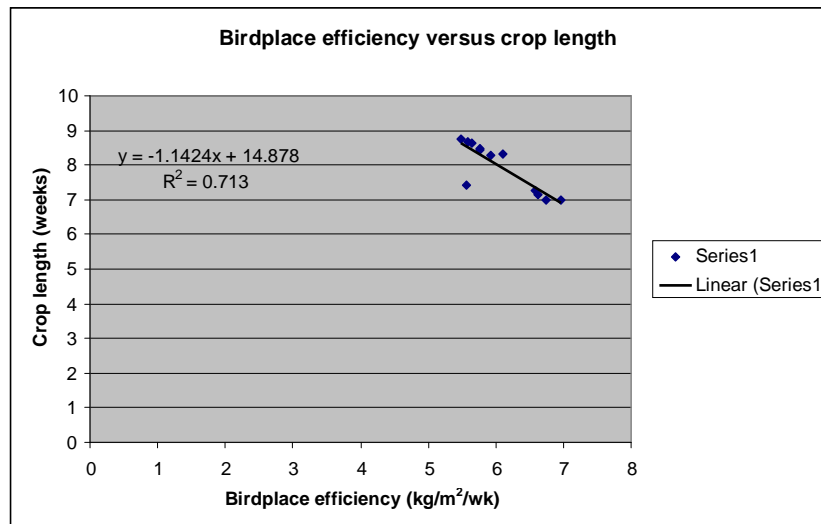
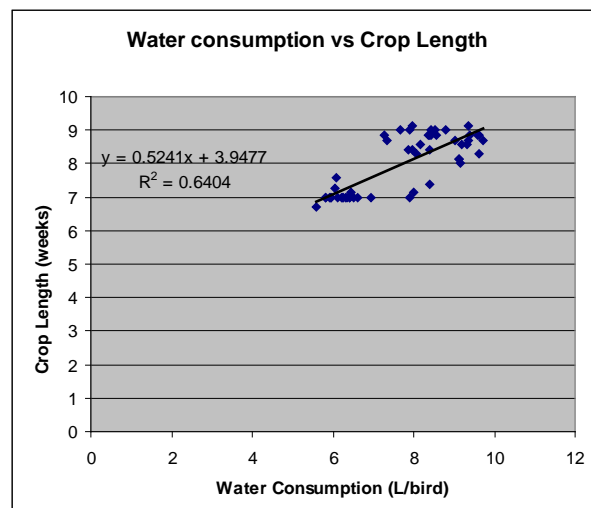


Figure 7.21: Water consumption by site compared to crop length



## Appendix 7 – Analysis of Benchmarking Data

Figure 7.22: Water consumption by crop compared to bird residence period

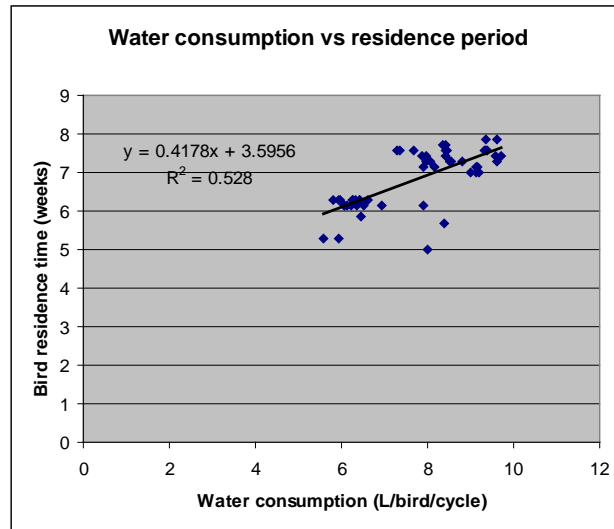


Figure 7.23: Water consumption by crop compared to average weight

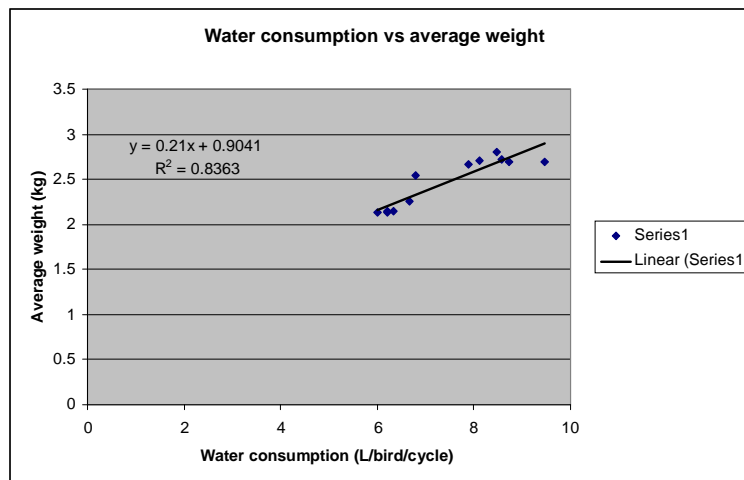
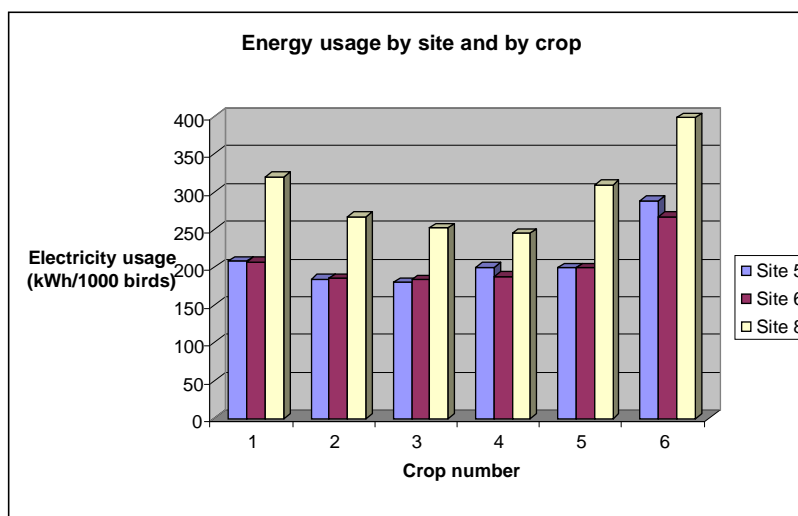


Figure 7.24: Comparison of annual electricity usage by crop across sites in kWh/1000 birds (bar chart)



## Appendix 7 – Analysis of Benchmarking Data

Figure 7.25: Comparison of electricity usage for four crops across six sites in kWh/1000 birds (bar chart)

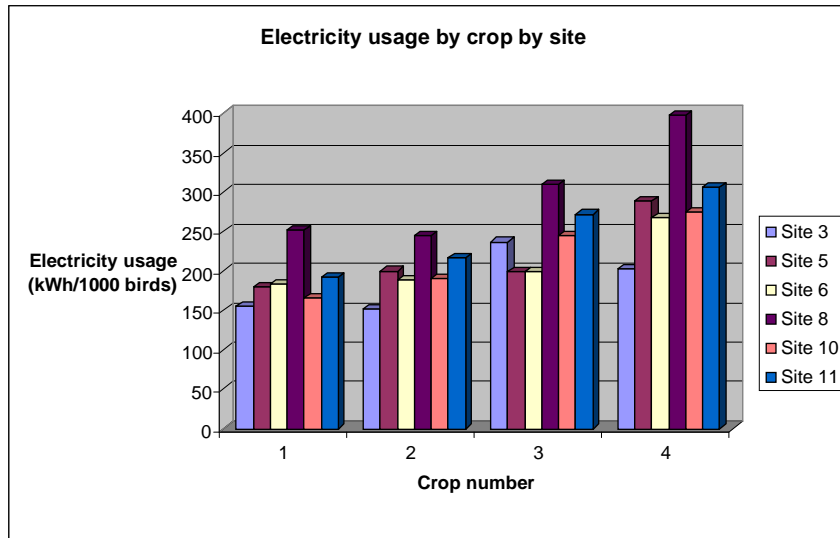


Figure 7.26: Comparison of crop length vs electricity usage for all crops

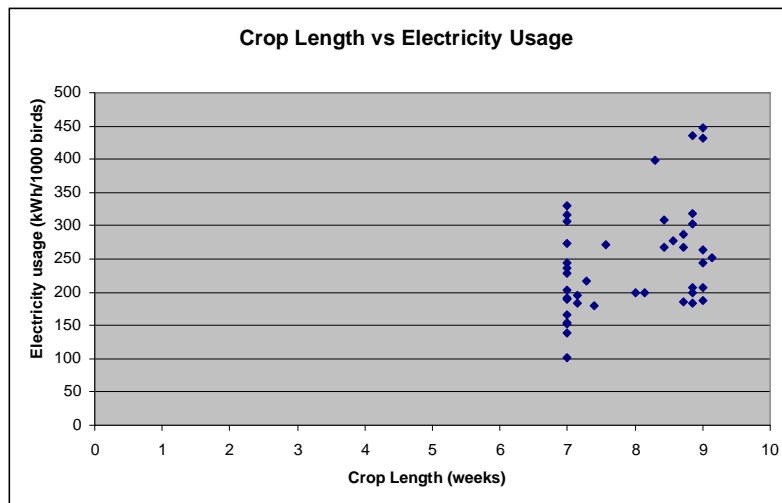
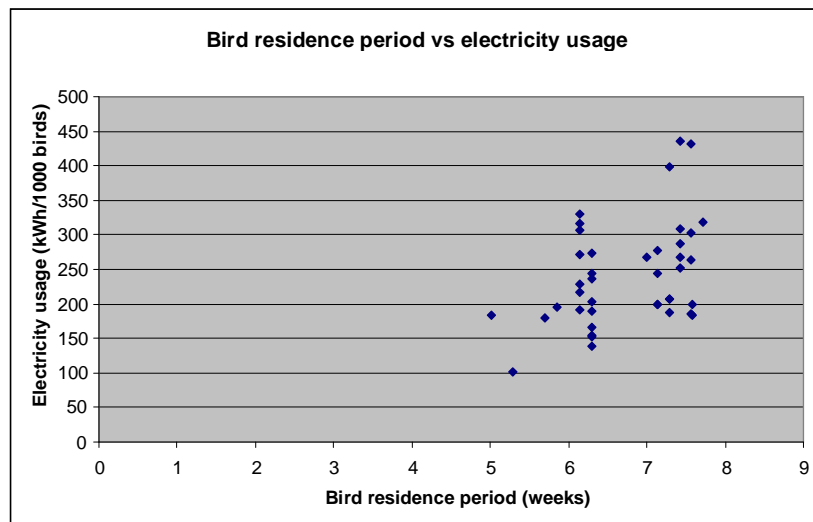


Figure 7.27: Comparison of bird residence period vs electricity usage for all crops



## Appendix 7 – Analysis of Benchmarking Data

Figure 7.28: Comparison of water usage vs electricity usage for all crops

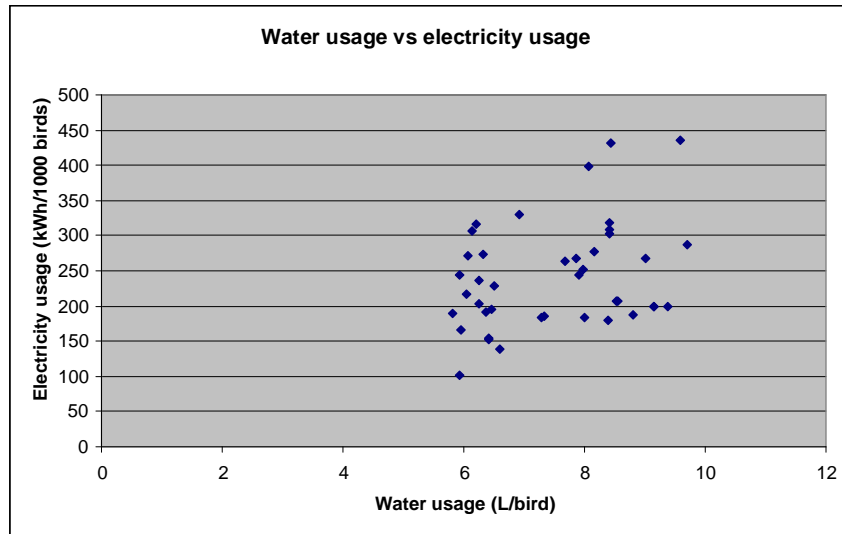


Figure 7.29: Average electricity usage for three sites in kWh/kg liveweight

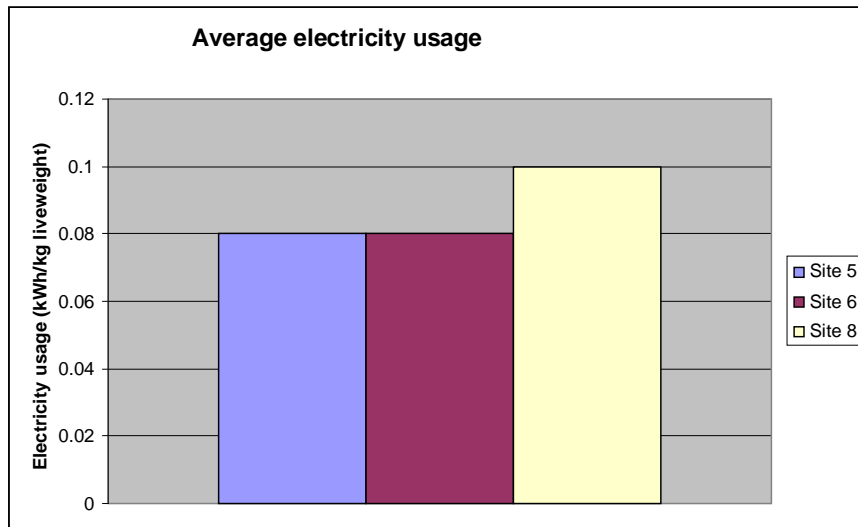
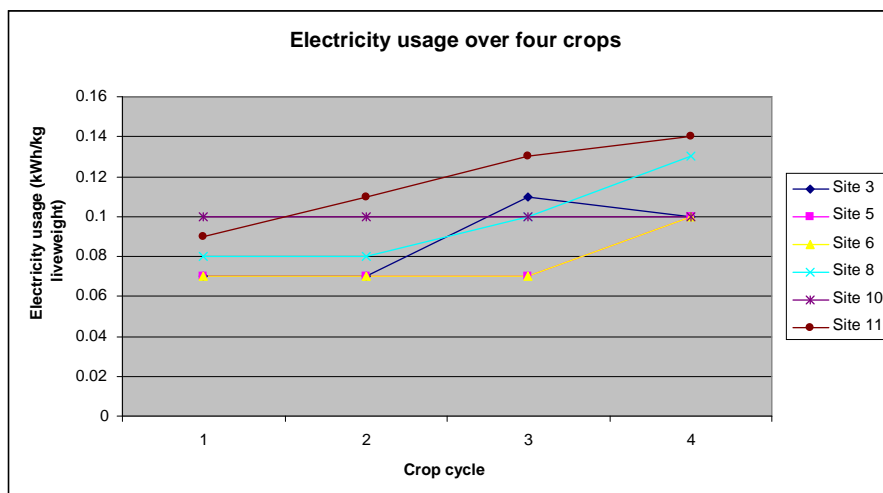


Figure 7.30: Comparison of electricity usage over four crop cycles across six sites in kWh/kg liveweight



## Appendix 7 – Analysis of Benchmarking Data

Figure 7.31: Comparison of annual electricity usage by crop across sites in kWh/kg liveweight (spider diagram)

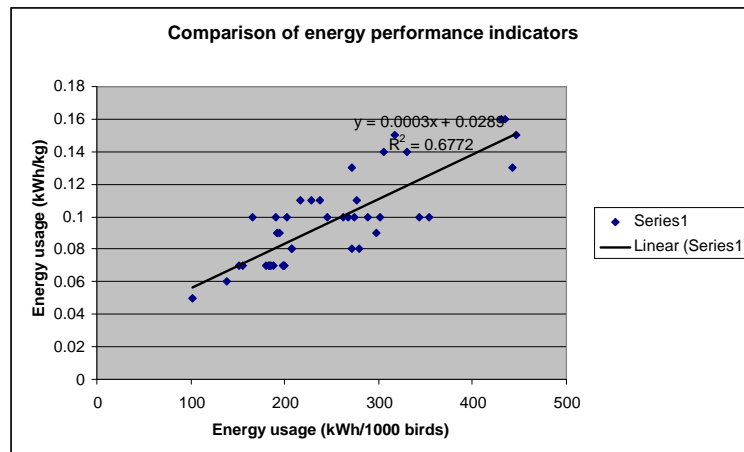


Figure 7.32: Comparison of annual gas usage across five sites in kWh/1000 birds (bar chart)

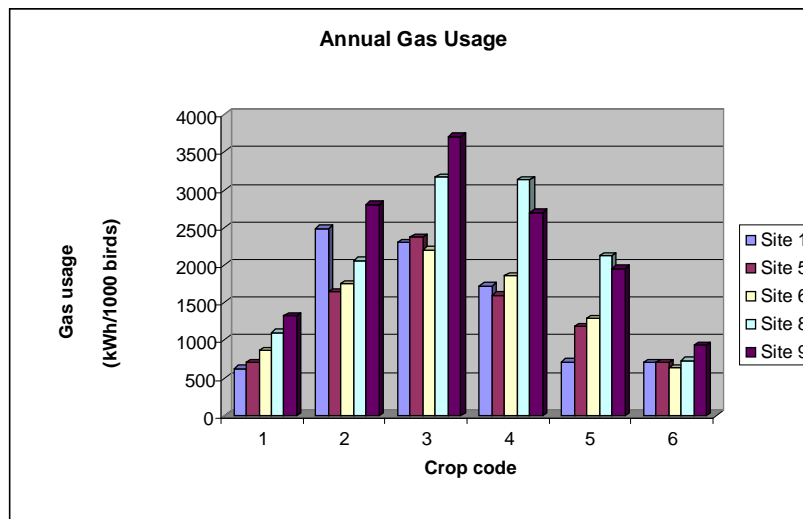
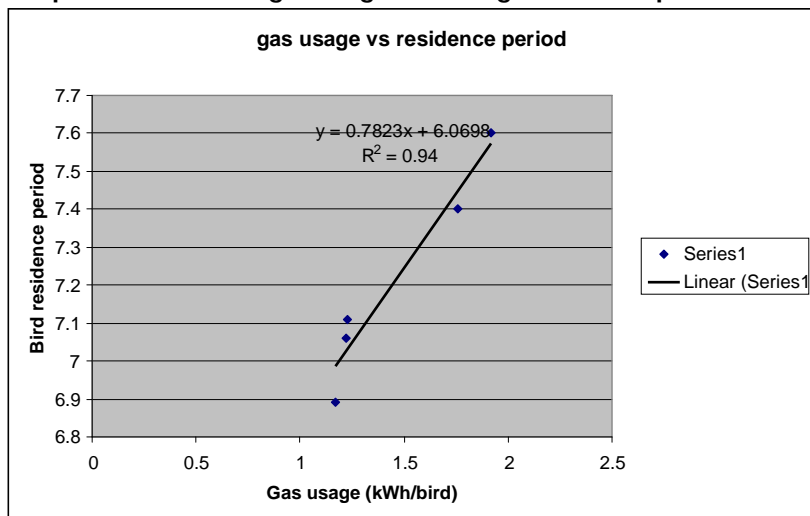


Figure 7.33: Comparison of annual gas usage vs average residence period for five sites



## Appendix 7 – Analysis of Benchmarking Data

Figure 7.34: Comparison of gas usage per crop across eight sites in kWh/1000 birds (bar chart)

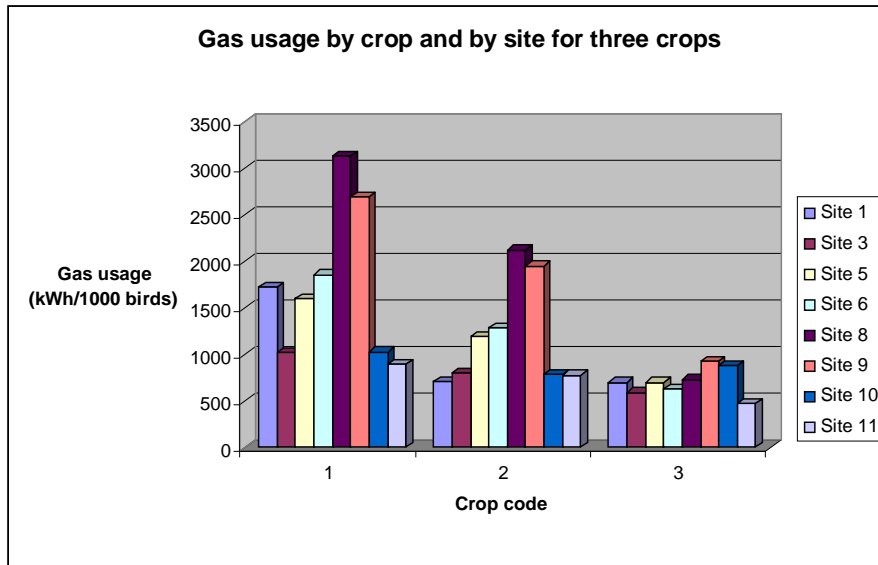


Figure 7.35: Comparison of gas usage for three crops across eight sites in kWh/1000 birds (Spider diagram)

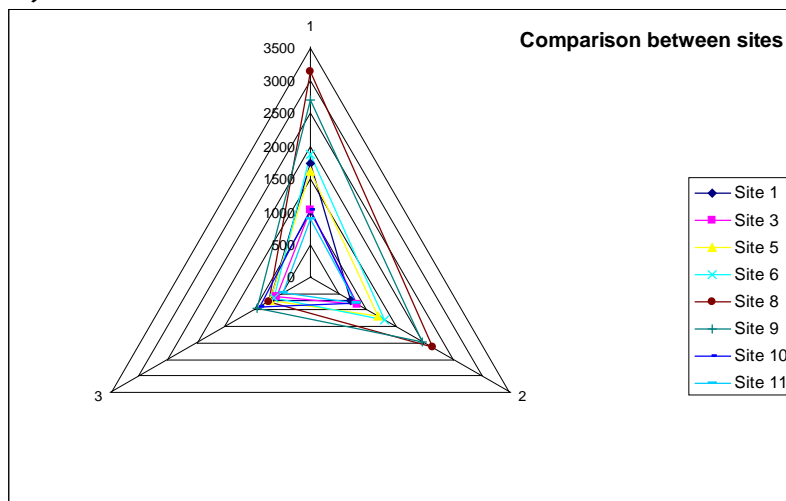
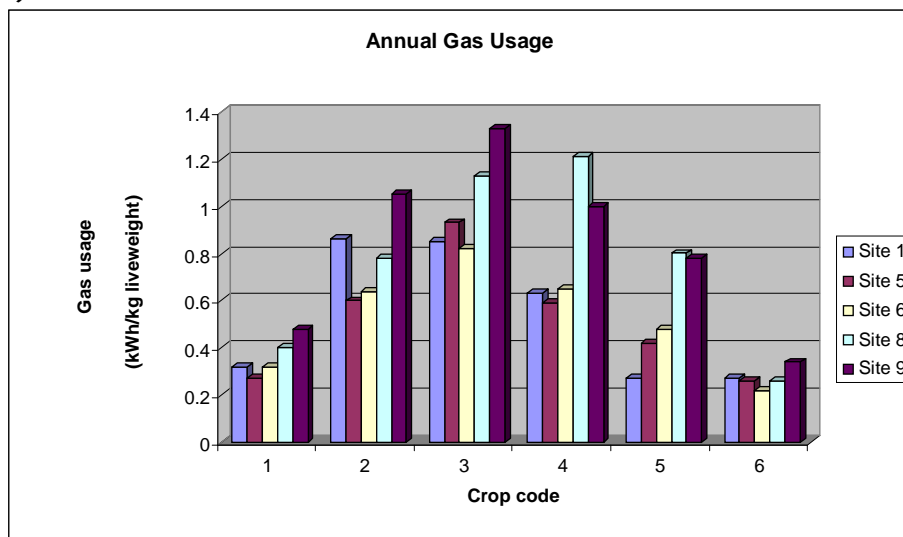


Figure 7.36: Comparison of annual gas usage per crop across five sites in kWh/kg liveweight (bar chart)



## Appendix 7 – Analysis of Benchmarking Data

Figure 7.37: Comparison of annual gas usage per crop across five sites in kWh/kg liveweight (Spider diagram)

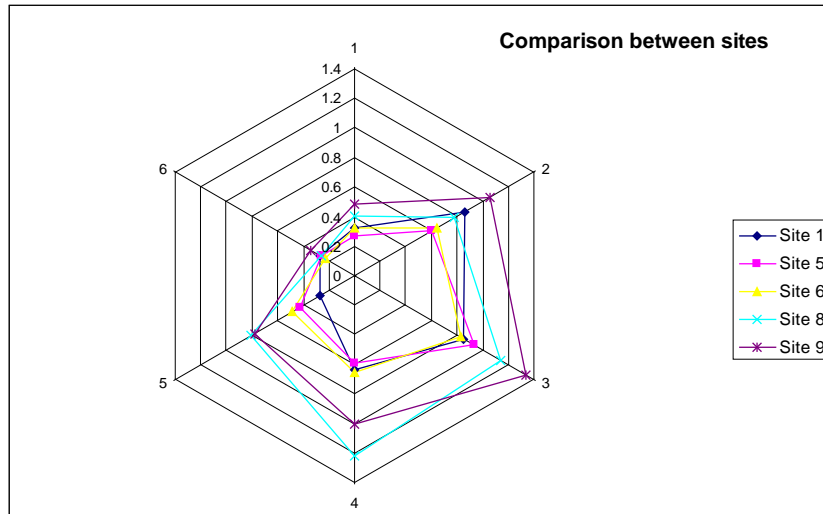


Figure 7.38: Comparison of total energy usage for four crops across six sites in kWh/1000 birds (spider diagram)

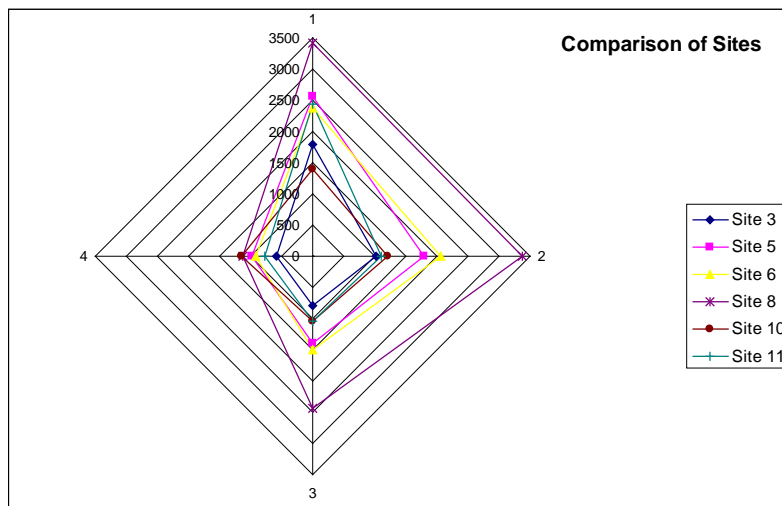
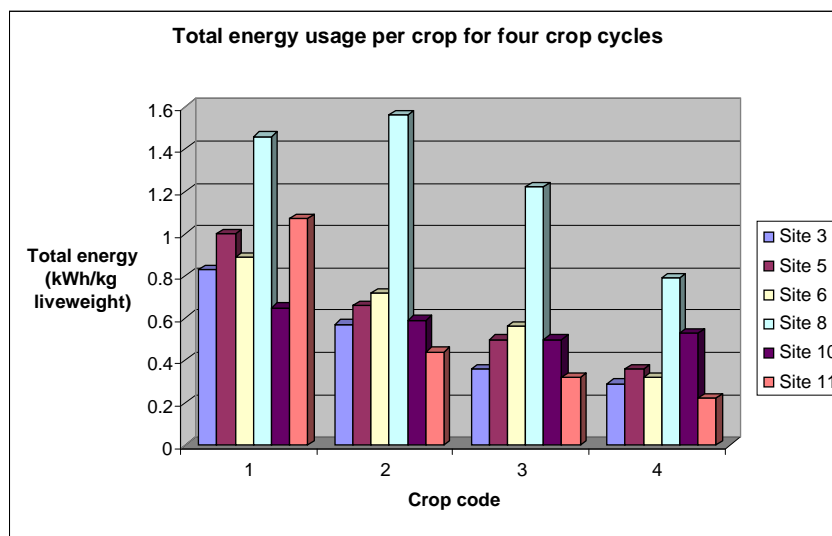


Figure 7.39: Comparison of total energy usage per kg liveweight for four crops over crop length for six sites.





## Appendix 7 – Analysis of Benchmarking Data

Figure 7.40: Comparison of water consumption by crop between Group 1 and Group 2 (L/bird/cycle)

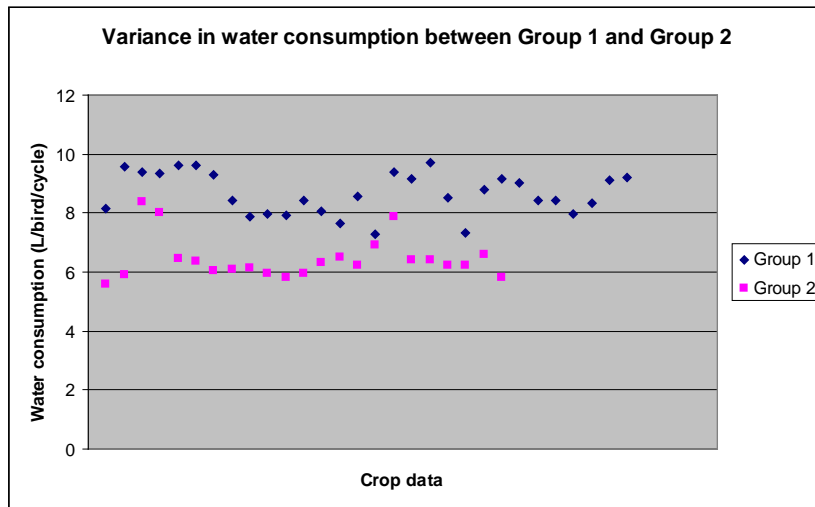
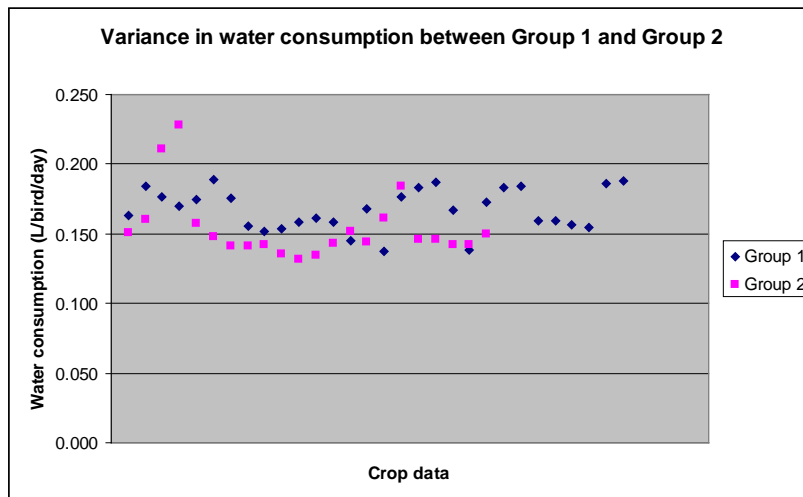


Figure 7.41: Comparison of water consumption by crop between Group 1 and Group 2 (L/bird/day)



## Appendix 8: Legislation and International Food Standards

(Written June 2005)

### Abstract

*This paper seeks to review key national (UK) and European legislation and its impact on the poultry meat supply chain. The following areas of legislation have been reviewed: food safety; environmental; conservation and biodiversity; animal welfare; health and safety and social legislation. The development of global food supply chains is a key driver in the harmonization of legislation, product and private assurance standards. Compliance with legislation and retailer requirements has been a key market driver in the development of private assurance standards. However these standards can largely only implement controls that the market can afford and there is always a commercial viewpoint with market based QA.*

### 1. International food standards

#### 1.1 Codex Alimentarius Commission (CAC)

The CAC was established following the eleventh session of the Conference of the Food Agricultural Organisation (FAO) in 1961 and the sixteenth World Health Organisation (WHO) Assembly in 1963. In 1998, membership comprised 163 countries, representing 97% of the world's population. The two bodies adopted the **Statutes** and **Rules of Procedure** for the Commission. The Statutes provide the legal basis for the Commission's work and formally reflect the concepts behind, and reasons for, its establishment. The Rules of Procedure of the CAC describe and formalize working procedures appropriate to an intergovernmental body. The Commission meets every two years, alternately at FAO headquarters in Rome and at WHO headquarters in Geneva, representation being on a country basis. A number of intergovernmental organizations (IGO) and international non-governmental organisations (NGO) also attend as "observers". The harmonization of food standards is generally viewed as a prerequisite to the protection of consumer health as well as allowing for facilitation of international trade.

The Uruguay Agreements on the Application of Sanitary and Phytosanitary Measures (SPS) and Technical Barriers to Trade (TBT) both encourage the international harmonization of food standards. Harmonisation is achieved when all countries adopt the same standards and Codex standards may be accepted by countries in a variety of forms including *full acceptance, acceptance with minor deviations and free distribution* as defined in Codex General Principles. The activities of the FAO and WHO complement the Commission's activities as in order to adopt Codex standards, there must be adequate food law in place and a suitable infrastructure to verify compliance. Article 1 (CAC, 2003) states that: "*The CAC shall .... Be responsible for making proposals to, and shall be consulted by, the Director General of the FAO and the WHO on all matters pertaining to the implementation of the Joint FAO/WHO Food Standards Programme, the purpose of which is:*

- a) protecting the health of consumers and ensuring fair practices in the food trade;*
- b) promoting coordination of all food standards work undertaken by international governmental and non-governmental organizations;*
- c) determining priorities and initiating and guiding the preparation of draft standards through and with the aid of appropriate organizations;*
- d) finalising standards elaborated under (c ) above and, after acceptance by governments, publishing them in a Codex Alimentarius either as regional or world standards, together with international standards already finalized by other bodies under (b) above, where this is practicable;*
- e) amending published standards, after appropriate survey in the light of developments."*

One of the principle purposes of the Commission as outlined in Article 1 is the preparation of food standards, their publication in the Codex Alimentarius and subsequent revision as the need arises. The procedure for this process is well defined, open and transparent and defined (Figure 1). There are two types of Codex Standards:

- a) **Commodity Standard** – product specific standards defining:
  - scope of the standard;
  - description, essential composition and quality factors;

- food additives;
- contaminants;
- hygiene and weights and measures;
- labelling;
- methods of analysis and sampling and;

b) **General Standard** – not product specific and address areas such as:

- food labelling;
- food additives;
- contaminants;
- methods of analysis and sampling;
- food hygiene;
- nutrition and foods for special dietary uses;
- food import and export inspection and certification systems;
- residues of veterinary drugs and foods;
- pesticide residues in foods.

As part of the literature review the current codex standards were reviewed and those pertaining either generally or specifically to the poultry meat supply chain are detailed in Appendix 1 of this paper.

## **1.2 United Nations Economic Commission for Europe (UNECE)**

As well as the standards developed by the CAC, the UNECE has been working for more than 50 years on commercial quality standards which can be used for international trading and as a reference point for quality control. The standardization activities of the UNECE include the harmonization of existing national standards into international commercial quality standards which can facilitate trade. The Working Party on Agricultural Quality Standards held a session in May 2003 to develop a draft UNECE Standard for Chicken Carcasses and Parts. The purpose of the standard is *"to facilitate trade by recommending an international language for raw (uncooked) chicken carcasses and parts (or cuts) marketed as fit for human consumption."* (UNECE, 2003). The

standard identifies both mandatory and optional purchaser specified categories for chicken product identification as follows:

### **Mandatory**

- **species** - chicken;
- **product/style**
- **bone** i.e. bone-in, partially boneless or boneless;
- **skin** i.e. skinless or skin (either white or yellow skin) and;
- **refrigeration** i.e. type of refrigeration.



**Figure 1: Steps in adopting a Codex Standard**

## Optional

- **class** – type of bird;
- **quality** – four levels 1-3 plus line run which is ungraded;
- **certification**;
- **product/feeding system**;
- **slaughter system** incl. conventional, halal, kosher.
- **post slaughter process** – method of chilling;
- **piece weight** - weight in grams, and;
- **additional product options**

### 1.3 World Health Organisation (WHO)

The WHO has a specific mandate for the global protection of public health and its role in food safety is to reduce the burden of foodborne illness by advising and assisting Member States (MS) to reduce exposure to unacceptable levels of chemicals or microorganisms in food. The WHO's central role includes international standard setting and the facilitation of risk assessments and to provide technical assistance to governments. The Fifty-third World Health Assembly in May 2000 gave unanimous support for Resolution WHA53.15 on food safety (WHO, 2003). This Resolution confirmed food safety as an essential public health priority and committed the WHO and its MS to promote the safety of food at local, national and international levels. It also resolved to expand the WHO's responsibilities in food safety, and the WHO developed a specific food safety strategy the goal of which is to reduce the health burden of foodborne disease. The issues raised in the strategy include:

- a risk-based approach should be used to set priorities for risk-reducing activities;
- cooperation between international agencies, especially FAO, must be improved and better links forged between national agencies involved in food safety to eliminate duplication, promote interdisciplinary work and increase the effectiveness of activities to reduce foodborne disease;

- the need for food safety systems based on a preventive approach, such as Hazard Analysis Critical Control Point (HACCP), especially in developing countries. These systems should be based on the premise that food safety is a priority for health;
  - effective participation of MS, especially developing countries, is needed in setting international standards and;
  - risk assessment, surveillance and capacity building contributing to reducing foodborne disease.
- The theme of foodborne disease is developed further by Manning *et al.*, (2005) which evaluates the potential for deliberate contamination of the food chain and its consequences.

#### 1.4 EU Marketing Standards

The **Poultrymeat Marketing Standards Regulations** were adopted on 1 July 1991 to facilitate harmonized standards throughout the EU for the marketing of poultrymeat intended for human consumption. They classify products by quality, weight, packaging (including labelling), water content and storage requirements and the criteria which need to be met in order to claim a certain type of farming standard otherwise known as **Special Marketing Terms** (SMT) e.g. free range. They apply to fresh, chilled, frozen or quick frozen whole carcasses, parts and offal of the following species of poultry (different legislation has different interpretations of the term "poultry"):

- domestic fowl (*Gallus domesticus* i.e. meat chickens and laying hens);
- ducks;
- geese;
- turkeys and;
- guinea fowl.

Under the SMT the stocking density for birds designated "free-range" is defined as 27.5 kg/m<sup>2</sup> in housing. This agrees with the standard defined in the European Retailers Integrated Farm Standard (EUREP, 2003) but not with the Freedom Foods Standard (RSPCA, 2002) which is 30 kg/m<sup>2</sup>. The

SMT define the age at slaughter as a minimum of 56 days whereas the Freedom Foods Standard identifies over 42 days as "a later age"- thus it could be argued that the Freedom Foods Standard does not comply with the terms "free range". The draft UNECE Standard for Chicken Carcasses and Parts and the EU Marketing Standards reference production standards including free range, but these international standards are not themselves cross-referenced in the farm production standards. It would "close the loop" if this cross-referencing was in place and it would aid transparency of farm production standards.

It was negotiated within the Uruguay Round of the World Trade Organisation (WTO) discussions that imports to the EU under minimum access quotas (Defra, 2003) benefit from a reduction in relevant basic tariff rates, and are subject to licensing arrangements laid down in Commission Regulations which for poultry are Regulations 1431/94 (zero duty) and 1251/96 (reduced duty). In addition in order to promote closer political and trade relations with Central and Eastern European (CEE) Countries, the EC has concluded Association Agreements with a number of CEE countries which include reduced duty import quotas for various poultry meat products. Trade negotiations are to take place between the EU and 76 countries of the African, Caribbean and Pacific. However it is not always clear at the point of purchase, the methods of production or indeed the differing legislation in the country of origin which could impact on the cost of production and the ability to be globally competitive.

## **2. Legislation**

### **2.1 Introduction**

The European Regulatory Framework has several instruments:

- **regulations** - come into force in MS immediately on publication;
- **decisions** - binding on parties such as MS or individual companies and;
- **directives** - require national legislation to implement their requirements into national law within a MS.

The biggest producer of poultry meat in the EU-15 (year 2000) was France (26% of EU-15 production); UK (17%); Italy (12%) and Spain (11%). The consumption of poultry meat in the EU



has steadily increased. From 1994 the UK has become the main consumer of poultry meat and its consumption has increased by 51% (IPPC BREF, 2003). The Defra Census, June 2002, identifies that 78,863,000 broilers are produced on registered holdings. The Poultry World (2003) state the total broilers placed between January and September 2002 was 616 million. This means that only around 12.8 % of broilers are produced on registered agricultural holdings. There are two types of broiler unit:

- a) stand-alone installations that bring in all their inputs and export all their outputs including litter; or
- b) the installation is one enterprise on a holding, for example, the scenario where the wheat for the broilers is grown and stored on the farm and the litter produced by the installation is utilised as a soil nutrient.

The impact of both current and future European environmental policy and legislation will differ between these two types of installation. The installations which fall into the second category will experience a much greater impact from existing and future legislation. The Agenda 2000 round of the CAP reform introduced the Rural Development Regulation (RDR) and established integrated rural development as the second pillar of the CAP. These changes will have far reaching impact on the broiler supply chain as one of the biggest costs is feed and variability in feed price will affect operating costs and the margins of profitability.

## **2.2 European Food Safety Legislation**

The major food safety legislation affecting the poultry supply chain at European and National level has been reviewed and is summarised in Appendix 2 of this paper.

### **2.2.1 Council Directive 93/43/EEC of 14 JUNE 1993 on the Hygiene of Foodstuffs**

This legislation is discussed in section 2.3.3.

### **2.2.2 EU White Paper on Food Safety 12 January 2000**

It is a key priority for the European Commission to have high standards of food safety and it was proposed in the white paper to set up an independent European Food Authority to guarantee the safety of food. The key tasks defined in the White Paper for the Authority were:

- reviewing scientific advice on all aspects of food safety;

- operation of rapid alert systems;
- communication and dialogue with consumers on food safety and health issues;
- networking with national agencies and scientific bodies, and to;
- providing the Commission with the necessary analysis so that it can decide on a suitable response.

A new legal framework was proposed which would encompass the food chain including animal feed production, establishing a high level of consumer protection and defining responsibility for food safety at each stage. It was also proposed that traceability throughout the food chain is a key requirement and controls would need to be put in place at both national and European levels to ensure food safety. The European Food Standards Agency (EFSA) is now in place and developing internal protocols having appointed committee members.

#### **2.2.3 Article 2 of Directive 2000/13/EC (food labelling)**

This requires that labelling, advertising and presentation of food must not be such that it could mislead a purchaser to a material degree, particularly as to characteristics of the food and, in particular, as to its nature, identity, properties, composition, quantity, durability, origin or provenance, method of manufacture or production; by attributing to the food effects or properties that it does not possess and by suggesting the food possesses special characteristics when in fact all similar foods possess such characteristics.

#### **2.2.4 Organic Schemes**

Organic schemes are regulated by the Council Regulation (EEC) 2092/91 and nationally by the Organic Products Regulations 2001.

### **2.3 National (UK) Food Safety Legislation**

National food safety legislation is defined in depth in Appendix 2 of this paper. Key legislation is defined in this section.

#### **2.3.1 The Trade Descriptions Act 1968**

This legislation makes it an offence to apply a false description to any goods, including specific information on quality, size and composition, how it was made and by whom.

#### **2.3.2 Food Safety Act 1990**

As described by Manning and Baines (2004), the Food Safety Act 1990 introduced into food safety law the concept of "due diligence". It was a new provision in place of the Food Act 1984. Under Part II of the main provisions of the Food Safety Act it details: *"S7 - (1) Any person who renders food injurious to health by means of any of the following operations, namely:*

- adding any article or substance to food;*
- using any article or substance as an ingredient in the preparation of the food;*
- abstracting any constituent from the food; and*
- subjecting the food to any other process or treatment,*
- with the intent that it shall be sold for human consumption shall be guilty of an offence."*

Thus it is an offence to sell food or specifically poultry products, which contain any article or substance rendering the food injurious to health e.g. physical (foreign body) or chemical contamination. Section 14 defines: *"14 (1) Any person who sells to the purchaser's prejudice any food which is not of the nature or substance or quality demanded by the purchaser should be guilty of an offence."* It is therefore an offence to sell food, which is of such inferior quality it would not be reasonable to expect the consumer to eat it, or has deteriorated to a point where it would not be fit to eat e.g. biological, bacterial, viral, mould or fungal contamination. The due diligence defence is also defined: *"... it shall .... Be a defence for the person charged to prove that he took all reasonable precautions and exercised all due diligence to avoid commission of the offence by himself or a person under his control."* The word "food" is defined in this legislation and the definition has subsequently been updated in The Food Safety (Amendment) Regulations 2004.

### **2.3.3 The Food Safety (General Food Hygiene) Regulations 1995**

The regulations aim to ensure common food hygiene rules across the European Community as set out in the Food Hygiene Directive (93/43/EEC) see 2.1.1. The regulations apply to all stages of food production except primary production and the legislation defines the requirements for hazard analysis, but not specifically the need to implement HACCP. *"A proprietor of a food business shall identify any step in the activities of the food business which is critical to ensuring food safety and ensure that adequate safety procedures are identified implemented, maintained and reviewed on*

*the basis of the following principles -*

- a) analysis of the potential food hazards in a food business operation;*
- b) identification of the points in those operations where food hazards may occur;*
- c) deciding which of the points identified are critical to ensuring food safety ("critical points");*
- d) identification and implementation of effective control and monitoring procedures at those critical points; and*
- e) review of the analysis of food hazards, the critical points and the control and monitoring procedures periodically, and whenever the food business's operations change."*

#### **2.3.4 The Food Safety (Temperature Control) Regulations 1995**

These regulations implement paragraph 4 and 5 of Chapter IX of the Annex to Council Directive 93/43/EEC on the hygiene of foodstuffs. The regulations apply to all stages of food production except primary production and came into force from 15 September 1995. The regulations require foods likely to support the growth of pathogenic micro-organisms to be stored below 8°C or above 63°C. Specific foodstuffs are not listed.

#### **2.3.5 The Meat (HACCP) (England) Regulations 2002**

This legislation requires that meat plant operators introduce hygiene procedures based on HACCP principles and to undertake microbiological checks in red meat plants.

### **2.4 Animal Welfare Legislation**

Broome (1996) defines welfare as "*the welfare of an animal is its state as regards its attempts to cope with its environment*". The welfare of poultry can be considered in relation to the housing environment and management practices it is subjected to (Puppe 1996, Rushen and de Passile 1992). Poultry welfare is discussed more fully in Working Paper seven and current animal welfare legislation is defined in Appendix 3 of this paper. Originally the focus of EU legislation with regard to animal welfare was on prevention of cruelty rather than recognizing animals as sentient beings with their own needs. The Treaty of Amsterdam 1999 introduced a "Protocol on the Protection and Welfare of Animals". This recognised animals as "*sentient beings*" and required the European Institutions to consider animal welfare when formulating and implementing Community legislation i.e. an "animal welfare impact assessment". The recognition of animal welfare as a constituent part

of European food policy was within the White Paper on Food Safety (see 2.2.2) and from January 2002 the European Scientific Advice on animal welfare issues is under the remit of the EFSA. The Commission has responsibility for ensuring that welfare laws are applied in a uniform manner across all MS. This is done through the European Food and Veterinary Office (FVO). The FVO carries out audits and on-the-spot checks in the MS. Animal welfare is not explicitly mentioned in the GATT Agreement 1994 or in other WTO Agreements, and there has not yet been a ruling under the dispute settlement procedure, which would define the position c.f. WTO. The 70<sup>th</sup> General Session of the Office International des Epizooties (OIE) or World Animal Health Organisation adopted a recommendation committing the OIE to take the lead on animal welfare. The EU is looking at developing bilateral agreements with regard to animal welfare but developments have been slow to date. Council Directive 98/58/EC concerns the protection of animals kept for farming.

The EU Commission asked Scientific Committee on Animal Health and Animal Welfare (SCAHAW, 2000) to produce a report on the Welfare of Chickens kept for Meat Production (Broiler) which was adopted on the 21 March 2000. This detailed report highlighted that for an adequate assessment of broiler welfare a range of indicators should be used. A Council Directive concerning the protection of chicken kept for meat production is proposed and consultation is currently being undertaken to determine the content. The Commission proposes to introduce an indicator based monitoring of the key factors of welfare at post-mortem inspection and seeks to allow higher stocking densities on well managed premises. In May 2004, the EFSA's Scientific Panel on Animal Health and Welfare (AHAW Panel) issued its opinion on the welfare of animals during transport. The Panel concluded that *"a variety of stressors involved in transport strongly contribute to poor animal welfare in particular for those species which are not used to human contact. Stress factors also increase the susceptibility to infections of transported animals and the shedding of infectious agents in those already infected. A high health status in the population of origin constitutes a major measure in preventing the spread of infectious diseases in relation to transport."* (EFSA, 2004). Specific measures were identified with respect to domestic fowl including requirements for health and welfare *"Mortality for domestic fowl increases with increasing transport time. Transport conditions,*

*health status, ventilation, and driving affect the extent of losses. Although mortality is often used as an indicator of transport conditions, it is a very poor measure of welfare, as animals may have suffered considerable pain and distress for some time prior to death'* and handling and allocation of space requirements.

#### **2.4.1 National (UK) Animal Welfare Legislation**

In 1964 in response to increasing public concern about intensive livestock production the Government appointed a Technical Committee under the Chairmanship of Professor Brambell to: *"examine the conditions in which livestock are kept under systems of intensive husbandry and to advise whether standards ought to be set in the interest of their welfare, and if so what they should be"*. The Committee recommendations included that new general and specific legislation was necessary to safeguard the welfare of farm animals and a statutory committee on farm animal welfare should be created. As a result the Farm Animal Welfare Advisory Committee (FAWAC) was set up in 1967 and statutory provisions for the welfare of livestock were introduced in the Agriculture (Miscellaneous Provisions) Act 1968 which makes it an offence to cause or allow livestock any unnecessary pain or distress. In 1979 the FAWAC was replaced by the FAWC. The Council was given the role of keeping under review the welfare of farm animals on agricultural land, at market, in transit and at places of slaughter, to advise the Agricultural Ministers on any legislative or other changes considered necessary. The Council is an independent body of agricultural, animal welfare, producer and academic interests, which has been given authority to consult with all parties and publish advice to Ministers. The general provision of The Protection of Animal Act 1911 made it an offence to ill-treat or cause unnecessary suffering to any animal. This has been amended by Protection of Animals (Amendment) Act 2000. The Code of Recommendations for the welfare of farmed animals (1987) was made under this act and was updated by the Code for the Welfare of Meat Chickens and Breeding Chickens issued 22<sup>nd</sup> July 2002 (Defra, 2002a). The major issues addressed are stockmanship and staffing, feed and water, health, mutilations, buildings and accommodation, stocking density and freedom of movement, automatic or mechanical equipment, record keeping, catching, handling and transport. There are also additional requirements for free-range birds' and recommendations for breeding chickens and

disposal for surplus chicks and embryos in hatchery waste. The Welfare of Farmed Animals (England) Regulations 2000 implement four EU Directives that set minimum standards for the welfare of all farm animals across the EU. These Regulations include 98/58/EC and cover all farmed animals and define the general requirements for general welfare, inspection, buildings and equipment, feeding and watering and additional provisions for specified species.

The current provisions of the Welfare of Animals Transport Order (1997) allow a maximum journey time for poultry of 12 hours when food and water is not available during the journey. In the case of poultry, journey times do not include loading and unloading times. Although there are some proposed changes where total journey time would begin when the first animal was loaded and would end once the last animals had been unloaded however time in crates off- vehicle in holding areas on farm or in slaughter houses would not be included as part of the journey.

## **2.5 EU Legislation on Employment Law and Employee Protection**

This area of legislation has been reviewed from the point of view of the impact on global competitiveness of employment law in the EU compared to other trade areas producing poultry. The major impact on integrated broiler production is the increased costs of the introduction of the national minimum wage (National Minimum Wage Act 1998) c.f. wages in Brazil or Thailand for equal work and the implementation of the EU Working Hours Directive as the Working Time Regulations 1998. If the UK loses its "opt-out" clause in the future then this too will have an impact on working hours, employee costs and numbers employed on poultry sites. Labour costs are a significant factor in the competitiveness of the EU industry compared with either South America or Thailand both in broiler growing and more specifically in the factories.

## **2.6 EU legislation on Health and Safety**

The need to comply with EU Health and Safety legislation also plays a significant role within broiler production. The level of legislation and the onus on the industry to provide proof of the management systems that assure workers of their safety is an integral part of broiler chain management. Health and Safety is one of the key factors which needs to be addressed in an

Integrated Management System and the farm assurance schemes have been reviewed to see how they best address this issue (Appendix 3 of this paper). National Health and Safety legislation includes:

- The Health and Safety at Work Act 1974;
- The Management of Health and Safety at Work Regulations 1994;
- The Control of Substances Hazardous to Health (COSHH) 1994;
- Code of Practice for the Safe Use of Pesticides (revised 1998) and;
- The Food and Environment Protection Act 1985 (FEPA).

## **2.7 EU Legislation on Environmental Policy**

The key drivers on an international level for increasing environmental legislation include climate change, the use of depleting natural resources including fossil fuels; the control of the phosphorous and nitrogen cycles i.e. the emissions of nitrogen and phosphorous to soil, surface water and groundwater; and integrated pollution control where "integrated" means an approach which looks at the combined impact on air, soil and water. The key environmental legislation is defined in Appendix 4 of this paper. Transporting food has in itself an environmental impact which is increasingly being identified by both internal and external business stakeholders. There is also a danger of merely transferring environmental problems to other regions of the world rather than addressing and reducing environmental impact on a global scale. As broiler production increases throughout Asia, as well as in South America, the environmental impact of both broiler production and meat processing needs to be addressed. The main environmental problems facing developing countries are:

- water pollution (industrialisation, domestic sewage, exhaustion of groundwater);
- air pollution (transport, energy, industry);
- waste management (increasing volume of household and industrial waste);
- land degradation (soil erosion, water logging and salinity);
- deforestation and;
- loss of biodiversity (loss of species and habitat).



### **2.7.1 Environmental Impact Assessment (EIA) Directive 85/337/EEC**

This directive requires that any proposal to use uncultivated land for intensive agricultural purposes is first assessed for significant environmental effects. EIAs are now well accepted within the planning process. The Town and Country Planning (EIA) (England and Wales) Regulations 1999 implement the Directive. The local authority has to undertake a formal process, a screening exercise, to identify if there are potentially significant environmental effects, if the floor area exceeds 500 m<sup>2</sup>. The contents of an EIA include airborne (dust, odour, noise), water (dirty and clean), landscape, highways, ecology (inc. ammonia) and alternative sites. The EIA is drawn together in a series of technical reports and provides the base line information for an IPPC Application.

### **2.7.2 Climate Change**

Burning fossil fuels in heating poultry houses emits gases (greenhouse gases) into the atmosphere, such as carbon dioxide, which are believed to contribute to long-term climate change. The results of this could include lower water levels in rivers and ground waters, particularly in summer. Winters are likely to become wetter and summers drier (Portugal, 1999). At the United Nations Conference on Environment and Development (UNCED, or the "Earth Summit") held in June, 1992, in Rio de Janeiro, Brazil, 178 countries adopted Agenda 21 which was a statement of willingness by countries to strive for a form of development that recognizes the essential links between economic growth, social equity and environmental protection. In providing guidelines for sustainable development, Agenda 21 seeks to ensure that development "meets the needs of the present without compromising the ability of future generations to meet their needs." (Netherlands, 2001)

The Commission on Sustainable Development (CSD) was created in December 1992 to ensure effective follow-up to the UNCED meeting, and to monitor and implement the agreements at the local, national, regional and international levels. In 1997, a 5-year review of Earth Summit, took place in New York. The 10-year review of Earth Summit progress, the World Summit on Sustainable Development (also known as Rio+10), took place in Johannesburg in 2002. In order to solve global environmental problems local action is also needed and the UK Local Agenda 21 initiative

encouraged local government and local communities to identify and begin to tackle a wide range of environmental issues. These included responsible use of natural resources, pollution, health, availability of local amenities and quality of life. The Environment Agency (EA) is committed to a programme of local action through Local Environment Agency Plans (LEAPs) which provide communities with a local agenda for environmental improvement. LEAPs translate the EA's long-term environmental strategy into target and action on the ground. The EA set out environmental goals, which addressed climate change, enhancing biodiversity and improving air quality. The EU's aim is to reduce greenhouse gases to a level that will not cause unnatural variations of the earth's climate and achieve the objectives of the Kyoto Protocol i.e. to reduce greenhouse gas emissions by 8% by 2008-2012 compared to 1990 levels. In the longer term by 2020 it will be necessary to reduce these emissions by 20 to 40% by means of an effective international agreement. (SCADPlus, 2001a). The aim is to reduce greenhouse gas emissions by an average of 1% per year over 1990 levels up to 2020. (SCADPlus, 2001b) Community efforts to meet the challenges of climate change include: (SCADPlus, 2001a).

- the integration of climate change objectives into various Community policies, in particular energy policy and transport policy;
- the reduction of greenhouse gases by means of specific measures to improve energy efficiency, to make increased use of renewable energy sources; to promote agreements with industry and to make energy savings and the establishment of an EU-wide emissions trading scheme;
- improved research on climate change;
- a review of energy subsidies and their compatibility with climate change objectives and;
- preparing society for the impact of climate change and the improvement of information on climate change.

A report was published in February 2003 setting out how UK government policy could be affected by climate change. The UK Government recognised that climate change could have a wide range of effects on the environment, society and the economy, from international issues like overseas development to internal issues such as transport policy and tourism. (Defra, 2003a) Key issues for

broiler production include:

- renewable energy from biomass;
- higher summer temperatures will have welfare implications for intensively housed livestock (ref. heat stress) and also animal transport. It will also have energy usage implications with regard to house heating and ventilation requirements;
- higher winter flooding could have implications for siting of buildings and changes to the rainfall pattern may lead to an increased need for on-farm reservoirs to conserve water and;
- higher frequency of summer droughts will mean decreased water availability for livestock this could also lead to changes in abstraction licensing; (this may well add to the costs for water used on the site).

In April 2001, UK businesses became liable for the Climate Change Levy (CCL), a new business energy tax that adds about 15% to energy bills. It has been introduced by the UK Government, as one policy in a range of policies to reduce emissions of greenhouse gases (including CO<sub>2</sub>) ref. Kyoto Protocol. It is charged on electricity, diesel and liquid petroleum gas (LPG). Intensive users of electricity such as poultry sites are able to join Climate Change Levy Agreements (CCLA) to help mitigate the effect of this tax. Under these agreements businesses must accept and subsequently meet milestone energy reduction targets and will in return receive a levy discount until the year 2013. The year 2010 has been set as a target to demonstrate improvement in performance from the energy consumption in the base year. If an installation exceeds its milestone target as well as making cost savings and improving on the installation's environmental impact, it will be able to trade its emission reduction as a "credit" to another company. It has been agreed with the EA that if an installation meets its targets under CCL it will be deemed to have met the IPPC energy efficiency requirements. The 1<sup>st</sup> milestone was April 2003, 2<sup>nd</sup> milestone April 2005 and then a milestone occurs every two years.

### **2.7.3 Landfill Directive (99/31/EC)**

The landfill directive was implemented in Member States by 2001. (OJ L 182). The Directive sets

targets to reduce land filling of biodegradable municipal waste to 75% of 1995 levels by 2006, 50% by 2009 and 35% by 2016. The anaerobic decomposition of biodegradable municipal waste in landfills produces emissions of methane, a green-house gas, so this legislation aims to reduce levels. The Directive banned land filling of whole tyres by 2003 and of shredded tyres by 2006. Existing landfill sites need to comply by 2009.

#### **2.7.4 EU Waste Incineration Directive 2000/76/EC**

The Waste Incineration Directive aims to reduce emissions to air, water and land from the incineration of non-hazardous wastes. When the Directive was negotiated, it was recognised that the controls were too onerous to permit the continued use of small animal carcase incinerators, thus there is an exemption for incinerators which burn only animal carcasses, on the understanding that appropriate controls would be included in the Animal By-Products Regulation. The controls applying to animal carcase incinerators are set out in Annex 1v of the EU Animal By-Products Regulation EC 1774/2002. The UK is believed to have around 2500 low capacity incinerators mainly on pig and poultry farms. Defra asked for a transitional period of at least two years (to the end of 2004) to enable them to visit all relevant premises and to bring them to full compliance with the Regulation. Defra has inspected premises to ensure that operations meet basic hygiene and technical standards i.e. animal by-products are handled and stored safely; incinerators operate to the required temperature (850°C) and incinerators reduce animal-by-products to dry ash and ash is disposed of properly and records are kept.

#### **2.7.5 EU Animal By-products Regulations EC 1774/2002**

Animal by-products are the carcasses, and parts of the birds, which are not intended for human consumption including blood, feather, litter and gut contents. The main disposal routes under the legislation are rendering or incineration, as land-fill and on-farm burial are no longer approved methods for carcase disposal. The Animal By-products Regulations 1999 were replaced by a new EU regulation from April 2003 (Defra, 2003). The regulation required the approval of the premises on which animal by-products are processed or disposed of and, for certain premises, the Regulation also sets the standards with which they must comply and operate. The Regulation established

transport conditions, documentation and record keeping requirements for both unprocessed and processed material i.e. it must be identified, transported in covered containers and accompanied by a commercial document or a health certificate. However this does not apply to "manure transported between two points located on the same farm or locally between farms and users located in the same Member State". (EU Official Journal, L 273). Certain products e.g. blood, feathers were exempt in some circumstances from the scope of the Animal By-Products Order but have to be treated in accordance with the Regulation. The legislation banned routine on-farm burial. Other methods of on-farm disposal are incineration as previously described or collection of carcasses for disposal. Compliance with this legislation has incurred substantial costs to the industry and created a commercial disadvantage for the UK market when competing with products from sources where this legislation is not implemented. The trade in unprocessed poultry manure is subject to the following conditions: (EU Official Journal, L 273)

- the manure must originate in an area, which is not subject to AI or ND restrictions;
- unprocessed manure from poultry flocks vaccinated against ND must not be dispatched to a region which has obtained ND non-vaccinating status pursuant to Article 15(2) of Directive 90/539/EEC (Official Journal, L 303) and (Official Journal, L 201) and a health certificate must accompany the manure.

Processed manure must come from an approved plant and must have been subject to a heat treatment of at least 70°C for 60 minutes or equivalent treatment. It also must be free from Salmonella (none detected in 25 g) and free from enterobacteriace and be subject to reduction in spore forming and toxin forming bacteria. It must be stored in such a way as to prevent secondary contamination or moisture uptake.

#### **2.7.6 EU Nitrates Directive 91/676/EEC**

The objective of the EU Nitrates Directive 91/676/EEC (EU Council Directive of 12 December 1991) is to reduce the risks related to high levels of nitrate in drinking water, acidification of soils and eutrophication of surface water. Nitrates are a health hazard in waters which are used as a source of drinking water. The Directive defines polluted waters as:

- surface freshwaters which contain or could contain, if preventative action is not taken,

nitrate concentrations greater than 50 mg/litre;

- ground waters which contain or could contain, if preventative action is not taken, nitrate concentrations greater than 50 mg/litre or;
- natural freshwater lakes or other freshwater bodies, estuaries, coastal waters and marine waters which are eutrophic (i.e. excessive nutrients have caused an accelerated growth of algae and plants, which affects the balance of organisms, including fish, and water quality).

The Directive requires the:

- establishment of a code of practice, to be implemented on a voluntary basis by farmers, to protect waters from pollution by nitrates;
- identification of waters polluted by nitrates from agricultural sources;
- identification of land areas contributing to the pollution and the designation of these lands as Nitrate Vulnerable Zones (NVZs);
- establishment of action programmes for designated NVZs within one year of designation, and implementation of these action programmes within four years of establishment.

MS are therefore required to identify zones, which drain into waters vulnerable to such pollution and thus require special protection. The legislation came into force in December 2002. There was a requirement to set up an "Action Programme" which includes nitrogen limits for organic manures, and closed periods when some manures cannot be spread. In these zones landspreading was restricted to 210 kg N/ha per year for arable land and this will be reduced to 170 kg N/ha after the first four years of the Action Programme in NVZ (Defra, 2002b). In 1996, NVZs were designated in England covering about 8% of the country this increased to 55% in 2002. In 2000 the combined area of all NVZ covered 38% of the total EU-15 land area (EC, 2001). Table 1 outlines the broiler places per hectare in relation to Nitrogen application rates (Defra, 2003)

**Table 1: Comparison of Broiler Places to land under NVZ restrictions**

	Existing GAP	Grassland NVZ	Arable NVZ	Arable NVZ
kg N/ha	250	250	210	170
Layers	380	380	320	260
Broiler Places	510	510	420	340

There are various uses for broiler poultry litter e.g. composting, power station fuel and use as a nitrogen source. Table 2 outlines the land required if all broiler litter from 616 million broiler bird

places in 2002 (Poultry World, 2003) was applied to land as outlined in Table 1 at the different nitrogen application rates. According to the June 2002 Census, the total land in England and Wales under arable cultivation was 4566 million hectares.

**Table 2: Land utilisation under NVZ restrictions**

	<b>Existing GAP</b>	<b>Grassland</b>	<b>Arable</b>	<b>Arable</b>
Poultry places Broiler	510	510	420	340
Hectares required to apply broiler litter	1.2 million	1.2 million	1.47 million	1.81 million
% Arable land (if total is 4.566 million)	26.3	-	32.2	39.6

This would mean that if all broiler litter was utilised as a soil nutrient it would require between 26.3 and 39.6% of all available arable land. This does not take into account other sources of manure, litter and slurry and demonstrates that we must have a clear national policy to developed further uses for poultry litter as with its dry matter content it is much better suited to use as an alternative fuel than other forms of farmyard manure. The EA in England and Wales enforces the NVZ regulations. The farmer should maintain records and retain them for a period of five years. Within the SFIR (2003) specific rules address nitrogen application.

#### **2.7.7 Integrated Pollution Prevention Control (IPPC) Directive 96/61/EC**

In Working Paper eight IPPC has been described in detail. Key issues for the sector include waste minimisation, water use, releases associated with energy use, emissions to air, effluent management, accident risk and hygiene and food safety. The activities which may have an affect on emissions and pollution include a power plant or generator, the control and abatement systems for emissions to air, land and water, and in meat processing the storage and handling of raw materials, washing, mixing and blending (tumbling), heating and cooking (frying); cleaning and storage and dispatch of finished products. The food and drink industry brought in IPPC (PPC Regulations 2000 No 1973 Schedule 3) from June 2004 onwards and this affected a large number of UK poultry processing plants and feed mills. The potential cost of compliance with the Standard Farming Installation Rules for broiler growing sites and the ongoing cost of the permit to operate will again impact on UK growers' competitiveness in a global market.

### **2.7.8 EU Waste Directives**

If any "specified waste management activity" is carried out, the regulator must not grant or transfer a permit unless the operator is a "fit and proper person" (FAPP) in relation to the carrying out of that duty. The Management of the activities should be in the hands of a technically competent person in accordance with Regulations 4 and 5 of the Waste Management Licensing Regulations 1994. The Waste Framework Directive covers IPPC activities involving the disposal or recovery of waste.

### **2.7.9 Packaging and Packaging Waste Directive 94/62/EC amd. 2002C/ 221/09**

The Directive was implemented in the UK through the Producer Responsibility Obligations (Packaging Waste) Regulations in 1997 (OJ C221). Businesses with a turnover above £2 million (after 2000) and handling over 50 tonnes of packaging per year have to register with the EA or a compliance scheme and supply annual packaging flow information to prove they are meeting their recycling and recovery obligations. Packaging Recovery Notes (PRN) are issued when recycling and recovery takes place, and can be traded between different businesses and compliance schemes. In 2000 the targets for recovery were increased to 58% recovery of packaging waste by 2001 and 18% material specific recycling. The objective is the harmonisation of national measures with a view to reducing the impact on the environment and the functioning of the internal market.

### **2.7.10 EU Water Framework Directive (2001/60/EEC)/ EC Groundwater Directive 80/68/EEC**

The main mechanism for controlling discharges of pollutants to water is licensing and monitoring. The Control of Pollution Act 1974 (COPA) controls discharges of poisonous, noxious or polluting substances to controlled waters. Authorisations for businesses contain conditions on both the quality and quantity of effluent, which can be discharged. From 1<sup>st</sup> April 1999 the Groundwater Regulations 1998 (which fully implement the Groundwater Directive) control the disposal of wastes containing certain listed substances. The Water Framework directive was adopted on 22 December 2000 and extended environmental protection for point and diffuse sources of pollution as well as impacts associated with water abstractions, dams and engineering works. The objective of the



directive is to establish a framework for community action in the field of water quality to protect inland surface waters, transitional water and ground water. The EC Water Framework Directive established a new integrated approach to the protection, improvement and sustainable use of Europe's rivers, lakes, estuaries, coastal waters and groundwater. The Directive requires surface waters to achieve "good" ecological and chemical status by 2015. Areas identified as Protected Areas must also achieve the objectives of the relevant Directives under which they are designated. There will therefore be considerable focus over the coming years on the use of organic manures and rather than being seen as a nutrient resource poultry litter may be deemed a "waste" that needs to be treated with the resultant cost.

#### **2.7.11 EC Habitats Directive 92/43/EC**

The Conservation (National Habitats etc) Regulations 1994 implement this directive on conserving natural habitats and wild flora and fauna. The biodiversity planning process came from the Rio Earth Summit where the 1992 Convention on Biological Diversity committed national signatories to produce plans for the conservation of Biodiversity in both national and local Biodiversity Action Plans (BAP). The UK government published its action plan in 1994 followed by Habitat Action Plans (HAPs) and Species Action Plans (SAPs). Agri-environmental schemes, along with English Nature's Wildlife Enhancement Agreements (WEAs), are therefore considered vital to achieving the Government's Public Service Agreement (PSA) target for Sites of Special Scientific Interest (SSSI) condition and helping the UK to meet its obligations under the EU Habitats Directive. Defra PSA targets include to reverse the long term decline in numbers of farmland birds by 2020 and to ensure 95% SSSIs have reached favourable condition by 2010.

### **3. Summary**

The legislation reviewed has had and will continue to have significant impact on the practices of broiler growing. Food safety legislation has been a key market driver in the development of private assurance standards. However these standards can largely only implement controls that the market

can afford and there is always a commercial viewpoint with market based QA. Safety of products sourced both inside and outside the EU needs not only to be both assured but also controlled by a regulatory framework to ensure that potential pathogens and other contaminants are adequately controlled within the food chain. Animal welfare legislation including the introduction of the proposed EU Broiler Welfare Directive will also have a significant impact on the industry. The House of Commons Environment, Food and Rural Affairs Committee (EFRAC, 2003) had fifty-eight conclusions and recommendations in their Committee report and concluded that *"without some form of intervention UK and EU poultry farmers will lose market share to overseas producers who do not have to meet such stringent animal welfare standards"* (Paragraph 58). The ongoing implementation of EU environmental legislation will add significant costs to the broiler industry. Potential savings through waste minimisation may alleviate some of the cost but the industry already undertakes detailed internal benchmarking to maximise margins so the potential saving on an industry already focusing on minimising costs could be limited.

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**EU Council Directive 2000/13/EC on food labeling**

**EU Nitrates Directive 91/676/EEC**

**EU Council Regulation (EEC) 2092/91** organic production

**EU IPPC Directive 96/61/EC**

**EU Environmental Impact Assessment (EIA) Directive 85/337/EEC**

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**The Code of Practice for the Safe Use of Pesticides (revised 1998)**

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**The Food Safety (Amendment) Regulations 2004**

**The Food Safety Act 1990**

**The Food Safety (General Food Hygiene) Regulations 1985**

**The Food Safety (Temperature Control) Regulations 1985**

**The Health and Safety at Work Act 1974**

**The Management of Health and Safety at Work Regulations 1994**

**The Meat (HACCP) (England) Regulations 2002**

**The Protection of Animals (Amendment) Act 2000**

**The Protection of Animal Act 1911**

**The Trade Descriptions Act 1968**

**The Welfare of Animals Transport Order (1997)**

**The Welfare of Farmed Animals (England) Regulations 2000**

**The Working Time Regulations 1998**

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### Appendix 8.1: CAC Standards relating to poultry meat production

Reference	Number	Year of adoption	Title	Revision	Year	Amendment	Year
CODEX STAN	107	1981	General Standards for the Labelling of Food Additives when sold as such				
CODEX STAN	192	1995	General Standard for Food Additives	3	2001		
CODEX STAN	192	1995	General Standard for Contaminants and Toxins in Foods	1	1997	1	2001
CODEX STAN	228	1989	General Methods of Analysis for Contaminants	2	2001		
CODEX STAN	234		Recommended Methods of Analysis and Sampling		1999	0	
CAC/RCP	1	1969	General Principles of Food Hygiene	3	1997	1	1999
CAC/RCP	11	1976	Fresh Meat	1	1993		
CAC/RCP	13	1976	Processed Meat and Poultry Products	1	1985		
CAC/RCP	14	1976	Poultry Processing				
CAC/RCP	20	1979	Code of Ethics for International Trade in Food	1	1985		
CAC/RCP	32	1983	Production, Storage and Composition of Mechanically Separated Meat and Poultry Meat intended for Further Processing				
CAC/RCP	38	1993	Control of the Use of Veterinary Drugs				
CAC/RCP	41	1993	Ante-Mortem and Post Mortem Inspection of Slaughter Animals and for Ante-Mortem and Post Mortem Judgment of Slaughter Animals and Meat.				
CAC/RCP	46	1999	Refrigerated Packaged Foods with Extended Shelf-life				
CAC/RCP	49	2001	Source Directed Measures to Reduce Contamination of Foods with Chemicals				
CAC/MRL	2		Maximum Residue Limits for Veterinary Drugs in Food	2001			
CAC/MRL	3		Extraneous Maximum Residue Limits (EMRLs)	2001			
CAC/MISC	1	1972	General Principles for the Use of Food Additives in Food				
CAC/MISC	4		Classification of Foods and Animal Feeds			1	2001
CAC/MISC	5	1993	Glossary of Terms and Definitions (Veterinary Drug Residues in Foods)				
CAC/MISC	6		List of Codex Advisory Specifications for Food Additives	12	2001		
CAC/GL	1	1979	General Guidelines on Claims	1	1991		
CAC/GL	2	1985	Nutritional Labelling	1	1993		
CAC/GL	14	1991	Guide for the Microbiological Quality of Spices and Herbs used in Processed meat and Poultry Products				
CAC/GL	15	1991	Use of Non-Meat Protein Products in Processed Meat and Poultry Products				
CAC/GL	16	1993	Guidelines for the Establishment of a Regulatory Programme for Control of Veterinary Drug Residues in Foods				
CAC/GL	19	1995	Exchange of Information in Food Control Emergency Situations				
CAC/GL	20	1995	Principles of Food Import and Export Certification and Inspection				
CAC/GL	21	1997	Principles for the Establishment and Application of Microbiological Criteria for Foods.				

Reference	Number	Year of adoption	Title	Revision	Year	Amendment	Year
CAC/GL	23	1997	Use of Nutrition Claims	1	2001		
CAC/GL	24	1997	Use of the Term Halal				
CAC/GL	25	1997	Exchange of Information between countries on Rejections of Imported Foods				
CAC/GL	26	1997	Design, Operation, Assessment and Accreditation of Food Import and Export Inspection and Certification Systems				
CAC/GL	27	1997	Assessment of the Competence of Testing Laboratories involved in the Import and Export Control of Foods				
CAC/GL	28	1995	Food Control Laboratory Management: Recommendations	1	1997		
CAC/GL	29	1985	General Requirements for Natural Flavourings				
CAC/GL	30	1999	Principles and Guidelines for the Conduct of Microbiological Risk Assessment				
CAC/GL	32	1999	Production, Processing, Labelling and Marketing of Organically Produced Foods	1	2001		

## Appendix 8.2: Food Safety Legislation

Some of this legislation also has an impact on animal welfare.

European	National
	<b>The Poultry Meat (Water Content) Regulations 1984</b> implements 2967/76/EEC which was replaced by 1538/91 (OJ No L143)
	<b>Imported Food Regulations 1984</b> replaced by the Imported Food Regulations 1997
	<b>The Meat Products and Spreadable Fish Products Regulations 1984</b>
	<b>The Weights and Measures (Packed Goods) Regulations 1985</b>
	<b>The Units of Measurement Regulations 1986</b>
	<b>The Weights and Measures (Quantity Marking and Abbreviation of Units) Regulations 1987</b>
	<b>The Weights and Measures (Quantity Marking and Abbreviation of Units) (Amendment) Regulations 1988</b>
	<b>Zoonoses Order 1989</b>
<b>Official Control Directive 89/397/EEC</b> This directive requires governments to enforce food hygiene legislation.	
<b>EC Marketing standards 1538/91</b> for fresh, frozen and quick frozen poultry meat – Poultrymeat (Marketing Standards) Regulations	
	<b>Food Safety Act 1990</b>
	<b>The Weights and Measures (Packed Goods) (Amendment) Regulations 1992</b>
	<b>Poultry Breeding Flocks and Hatcheries Order 1993</b>
	<b>The Units of Measurement Regulations 1994</b> implements 80/181/EEC as amended by 85/10/EEC and 89/617/EEC
	<b>The Weights and Measures (Packed Goods) (Amendment) Regulations 1994</b>
	<b>The Weights and Measures (Packed Goods and Quantity Marking and Abbreviation of Units) (Amendment) Regulations 1994</b> implements 75/106/EEC as amended by 78/891/EEC and 79/005/EEC 76/211/EEC as amended by 78/891/EEC
	<b>The General Product Safety Regulations 1994</b> implements 92/59/EEC (OJ No L228)
	<b>Meat Products (Hygiene) Regulations 1994</b> implements 92/5/EEC
<b>Council Directive 93/43/EEC</b> of 14 JUNE 1993 on the Hygiene of Foodstuffs see section 6.2.1	<b>Food Safety (General Food Hygiene) Regulation 1995</b> , 1999 – implements 93/43/EEC, 80/778/EEC (OJ No L229), 95/68/EC (OJ No L332), 97/76/EC (OJ No L10) and 92/5/EEC.
	<b>Food Safety (Temperature Control) Regulations 1995</b> implements part of 93/43/EEC post slaughter
	<b>Fresh Meat (Hygiene &amp; Inspection) Regulations 1995, 1996, 1997</b> implements 91/497/EEC, 91/495/EEC
	<b>Poultry Meat, Farmed Game Bird Meat &amp; Rabbit Meat (Hygiene &amp; Inspection) Regulations 1995</b> implements 91/495/EEC (OJ No L268), 71/118/EEC (OJ No L55), 92/116/EEC (OJ No. L62).
	<b>The Minced Meat and Meat Preparations (Hygiene) Regulations 1995</b> implements 94/65/EC (OJ No. L368)
	<b>The Fresh Meat (Hygiene and Inspection) Regulations 1995</b>
	<b>The Food Labelling Regulations 1996</b> implements 79/112/EEC (OJ No. L33)

European	National
	<b>The Food (Lot Marking) Regulations 1996</b> implements 89/396/EEC
	<b>Products of Animal Origin (Import and Export) Regulations 1996</b> implements 89/662/EEC (OJ No L395), 92/118/EEC (OJ No. L62), 90/675/EEC (OJ No L373), and 97/78/EC (OJ No L24) and import/export controls.
	<b>Products of Animal Origin (Import and Export) (Amendment) Regulations 1997</b> implements 96/43/EEC (OJ No L162), 97/132/EEC (OJ No. L57),
	<b>Animals and Animal Products (examination for Residues and Maximum Residue Limits) Regulations 1997</b> implements 96/22/EC and 96/23/EC
<b>Product Liability Directive 99/34/EC</b> This covers all goods.	
	<b>The Materials and Articles in contact with food regulations 1997</b> implements 83/229/EEC (OJ No L123) and 86/388/EEC
	<b>The Plastic Materials and Articles in contact with Food Regulations 1998</b> implements 97/48/EC (OJ No L222) and 82/711/EEC.
	<b>The Imported Food Regulations 1997</b>
	<b>The Meat (Hygiene and Inspection) (Charges) Regulations 1998</b>
	<b>The Medicated Feedstuffs Regulations 1998</b> implements 90/167/EEC
	<b>The Food Standards Act 1999 (Transitional and Consequential Savings) (England and Wales) Regulations 2000.</b>
	<b>The Feeding Stuffs (Zootechnical Products) Regulations 1999</b> implements 70/524/EEC (OJ No L270) and 96/51/EC (OJ No L235)
	<b>The Food Safety (General Food Hygiene) (Amendment) Regulations 1999</b>
	<b>The Meat Products (Hygiene) (Amendment) Regulations 1999</b>
	<b>The Feeding Stuffs (Establishments and Intermediaries) Regulations 1999</b> implements 95/53/EC (OJ No L265), 95/69/EC (OJ No L332), 96/51/EC (OJ No L235), 98/51/EC (OJ No L208)
	<b>The Feeding Stuffs (Enforcement) Regulations 1999</b> implements 95/53/EC (OJ No L265), 98/68/EC (OJ No L261)
	<b>The Feeding Stuffs (Sampling and Analysis) Regulations 1999</b> implements 70/373/EEC, 93/28/EEC (OJ No L179), 94/14/EEC (OJ No L94), 98/88/EC (OJ No L138)
<b>EU Animal By-products Regulations EC 1774/(2002)</b>	<b>Animal By-products Order 1999</b> replaces three previous orders and implements 90/667/EEC (animal waste disposal), 92/562/EEC (alternative heat treatments), 94/382/EC (alternative heat treatments), 96/449/EEC (alternative heat treatments), 95/348/EC (veterinary health rules of animal waste and use as a feedstuff).
	<b>The Plastic Materials and Articles in contact with Food (Amendment) (England) Regulations 2000</b> implements 1999/91/EC (OJ No L310)
	<b>The Feeding Stuffs Regulations 2000</b> implements 70/524 EEC (OJ No L270), 79/373/EEC (OJ No L86), 80/511/EEC OJ No L125), 82/471/EEC (OJ No L213), 91/516/EEC (OJ No L281), 93/74/EEC (OJ No L237), 96/25/EC (OJ No L125), 1999/29/EC (OJ No L115), 1999/79/EC (OJ No L209)
	<b>The Meat (Enhanced Enforcement Powers) (England) Regulations 2000</b>



European	National
	<b>The Meat (Disease Control) (England) Regulations 2000</b>
	<b>The Meat Products (Hygiene) (Amendment) Regulations 2000</b>
	<b>The Food Safety (General Food Hygiene) (Butchers' Shops) Amendment Regulations 2000</b>
	<b>The Poultry Meat, Farmed Game Meat, and Rabbit Meat (Hygiene and Inspection) (Amendment) (England) Regulations 2001</b>
	<b>The Weights and Measures (Metrication) Regulation 2001</b> implements 1999/103/EC
	<b>The Organic Products Regulations 2001</b>
	<b>The Animal By-products (Amendment) (England) Order 2001.</b>
	<b>Animals and Animal Products (examination for Residues and Maximum Residue Limits) Amendment Regulations 2001</b>
	<b>The Feeding Stuff and Feeding Stuff (Enforcement) (Amendment) (England) Regulations 2001</b>
	<b>Meat (HACCP) (England) Regulations 2002</b>
	<b>The Medicated Feedstuffs (Amendment) (England, Scotland and Wales) Regulations 2002</b>
	<b>The Product of Animal Origin (Third Country Imports) (England) Regulations 2002</b> implements 97/78/EC (OJ No L24)
	<b>The Animal By-products (Identification) (Amendment) (England) Regulations 2002</b>
	<b>The Animal By-products (Identification) (Amendment) (England) (No 2) Regulations 2002</b>
	<b>The Animal By-products (Identification) (Amendment) (England) Regulations 2003</b>
	<b>The Organic Products (Imports from Third Countries) Regulations 2003</b>
2001/46/EC	<b>The Feedstuffs (Enforcement) (Amendment) Regulations 2003</b>
	<b>The Feeding Stuff, The Feeding Stuff (Sampling Analysis and the Feeding Stuff (Enforcement) (Amendment) (England) (No 2) Regulations 2003</b>
2003/57/EC and 2003/104/EC	<b>The Feeding Stuff, The Feeding Stuff (Sampling Analysis and the Feeding Stuff (Enforcement) (Amendment) (England) Regulations 2004</b>
	<b>The Food Safety (Amendment) Regulations 2004</b>
	<b>General Food Regulations 2004</b>
	<b>The Food Hygiene (England) Regulations (2005)</b>

### Appendix 8.3: Animal Welfare Legislation

European	National
Veterinary Checks intra community in the single market are addressed by council directives 89/662/EEC and 90/425/EEC	<b>The Protection of Animals Act 1911.</b> This has been amended by Protection of Animals (Amendment) Act 2000.
Imports from third countries are addressed by 97/78/EEC and 91/496/EEC	<b>The Veterinary Surgeons Act 1966</b>
	<b>Agriculture (Miscellaneous Provisions) Act 1968</b>
	<b>Welfare of Livestock (Intensive Units) Regulations 1978.</b>
	<b>Animal health Act 1981</b>
	<b>Slaughter of Poultry (Humane Conditions) Regulations 1984</b>
	<b>Diseases of Animals (Approved Disinfectants) Order 1978</b>
	<b>Specified Animal Pathogens Order 1998</b> implements 92/118/EEC
	<b>Zoonoses Order 1989</b>
	<b>The Poultry Breeding Flocks and Hatcheries (Registration and Testing) Order 1989.</b> Amended 1990.
	<b>The Medicines Orders 1991, 1998, 1984, 1997.</b>
	<b>Poultry Breeding Flocks and Hatcheries Order 1993</b>
	<b>The Marketing Authorisations for Veterinary Medicinal Products Regulations 1994</b>
	<b>Welfare of Livestock Regulations 1994, 1998</b>
	<b>Diseases of Poultry Order 1994</b> implements 92/40/EEC (avian influenza) and 92/66/EEC (Newcastle disease)
	<b>The Importation of Animal Products and Poultry Products Order,</b> as amended 1980; 1994 prohibits landing in GB of poultry product from outside GB except under authority of a licence with specific exemptions.
	<b>The Welfare of animals during Transport Order 1994</b> implements 91/268/EEC (OJ No L340)
	<b>The Welfare of Animals (Slaughter or Killing) Regulations 1995, 1999 and the Welfare of Animals (Slaughter or Killing) (England) (Amendment) Regulations 2000.</b>
	<b>Specified Diseases (Notification) Order 1996</b>
	<b>Animals and Animal Products (examination for Residues and Maximum Residue Limits) regulations 1997</b> implements 96/22/EC and 96/23/EC
	<b>The Medicines (Veterinary Drugs) (Pharmacy and Merchants' List) (Amendment) order 1997</b>
	<b>Welfare of Animals (Transport) Order 1997</b>
	<b>Animal By-Products (Identification) Regulations</b> as amended 1997 poultry excluded addresses staining or sterilisation procedures.
	<b>Animal and Animal Products (Examination for Residues and Maximum Residue Limits) Regulations 1997</b> implements 96/22/EC (prohibits use in stock farming of hormonal or other agents) and 96/23/EC measures to monitor for these substances.
	<b>Animals and Animal Products (Import and Export) regulations 1998.</b> Amended to (England and Wales) Regulations 2000
	<b>The Diseases of Animals (Approved Disinfectants) (Amendment) Order 1999</b>
<b>EU Animal By-products Regulations EC 1774/(2002)</b>	<b>Animal By-products Order 1999</b> replaces 3 previous orders and implements 90/667/EEC (animal waste disposal), 92/562/EEC (alternative heat treatments), 94/382/EC (alternative heat treatments), 96/449/EEC (alternative heat treatments), 95/348/EC (veterinary health rules of animal waste and use as a feedstuff.
	<b>The Welfare of Farmed Animals (England) Regulations 2000</b> implemented 98/58/EC.
	<b>The Animal Health Act 2002</b>
	<b>The Welfare of Farmed Animals (England) Regulations 2002</b> amended from 2000 regulations.
	<b>Diseases of Poultry (England) Order 2003</b>
	<b>The Transport of Animals (Cleaning and Disinfection) (England) Order 2003</b>
	<b>The Avian Influenza and Newcastle Disease (England and Wales) Order 2003</b>

## Appendix 8.4: Environmental Legislation

European	National
	<b>The Control of Pollution Act 1974</b>
	<b>The Wildlife and Countryside Act 1981</b>
	<b>Control of Pesticides Regulations 1986 1986 (COPR) (Amended 1997)</b>
	<b>Control of Pollution Silage, Slurry, and Agricultural Fuel Oil Regulations 1991 (Amended 1997)</b>
	<b>The Water Resources Act 1991</b>
<b>EU Nitrates Directive 91/676/EEC</b>	
<b>EC Habitats Directive 92/43/EC</b>	<b>Conservation (National Habitats etc) Regulations 1994</b>
<b>EU Waste Management Licencing Directive</b>	<b>Waste Management Licensing Regulations 1994</b>
	<b>Wild Mammals (Protection) Act 1996</b>
	<b>The Pesticides Act 1998</b>
<b>EC Groundwater Directive 80/68/EEC</b>	<b>Groundwater Regulations 1998</b>
	<b>Animal By-Products Order 1999</b>
<b>Environmental Impact Assessment (EIA) Directive 85/337/EEC</b>	<b>Environmental Impact Assessment (EIA) Regulations 1999</b>
<b>EU Animal By-products Regulations EC 1774/(2002)</b>	<b>Animal By-products Order 1999</b> replaces three previous orders and implements 90/667/EEC (animal waste disposal), 92/562/EEC (alternative heat treatments), 94/382/EC (alternative heat treatments), 96/449/EEC (alternative heat treatments), 95/348/EC (veterinary health rules of animal waste and use as a feedstuff.
<b>Landfill Directive 99/31/EC</b>	
<b>Incineration Directive 2000/76/EC</b>	
<b>Packaging and Packaging Waste Directive 94/62/EC amendments 2002C/ 221/09)</b>	<b>Producer Responsibility Obligations (Packaging Waste) Regulations 1997</b>
<b>Water Framework Directive 2000/64/EC</b>	
<b>EU Nitrates Directive 91/676/EEC</b>	
<b>European Community (EC) Directive 96/61/EC on Integrated Pollution Prevention and Control</b>	<b>Pollution Prevention and Control (England and Wales) Regulations 2000; Pollution Prevention and Control (Scotland) Regulations 2000; Pollution Prevention and Control Regulations (NI) 2003.</b>
<b>EU Animal By-products Regulations EC 1774/(2002)</b>	<b>Animal By-products Order 1999</b> replaces three previous orders and implements 90/667/EEC (animal waste disposal), 92/562/EEC (alternative heat treatments), 94/382/EC (alternative heat treatments), 96/449/EEC (alternative heat treatments), 95/348/EC (veterinary health rules of animal waste and use as a feedstuff.

### Appendix 9.1: Comparison of farm assurance standards

1.1	Scheme Name	EUREP IFA January 2003	Assured Chicken Production Broiler Standard 2003/2004	Assured Chicken Production Free Range Standard 2003/2004	Freedom Foods January 2002	Soil Association July 2000
1.2	Scope of Scheme – Production Methods Covered	Modules: Farm, Poultry Livestock Road Transport Livestock (Base)	Breeder/Broiler Hatchery Catching Transport Slaughter	Breeder/Broiler Hatchery Catching Transport Slaughter	Chicken Production Catching Transport Slaughter	Breeder/ Free Range Catching Transport Slaughter
1.3	Purpose of Scheme - has the Scheme been set up to provide evidence of compliance with:					
1.3.1	Food safety legislation	√	X	X	X	X
1.3.2	Welfare legislation	√	√	√	√	√
1.3.3	Health and safety legislation	√	√	√	X	X
1.3.4	Environmental legislation	√	√	√	√	X
1.3.5	Animal medicines legislation	√	√	√	√	X
1.3.6	Higher welfare standards	√	X	√	√	√
1.3.7	EU Free range standards	X	N/a	√	√	X
1.3.8	Social accountability protocols	√	X	X	X	X
1.4	Does the scheme reference the following:					
1.4.1	Codex Alimentarius Commission	X	X	X	X	X
1.4.2	Hazard Analysis Critical Control Point (HACCP)	X	X	X	X	X
1.4.3	ISO Standards ISO9000 or ISO14000 series	X	X	X	X	X
1.4.4	GAP Codes – Air, Soil, Water	√	√	√	√	X
1.4.5	Five Freedoms or FAWC	X	√	X	√	√
1.4.6	Welfare Codes	X	√	X	√	√
1.4.7	European Convention on Farm Animals	X	X	X	X	√
1.4.8	ILO, ETI Standards	√	X	X	X	X
1.4.9	Responsible Use of Medicines in Agriculture Alliance RUMA Code for Anti-microbials	X	√	√	X	X
1.4.10	Key Performance Indicators	X	√	X	√	X
1.5	Does the scheme require the following policies:					
1.5.1	Farm Site Plan and Emergency Plan	√	√	√	√	X
1.5.2	Health and Hygiene Plan	√	√	√	(in feed and water)	√
1.5.3	Management and Stockmanship Module	√	√	√	√	X
1.5.4	Feed and Water Module	√	√	√	√	√
1.5.5	Bird Environment Module	√	√	√	√	√
1.5.6	Provision for Chicks	√	√	√	√	X
1.5.7	Documentation/Records	√	√	√	√	√
1.5.8	Depopulation Standards	√	√	√	√	X
1.5.9	Breeder layer flock provisions – egg collection,	√	√	√	X	X
1.5.10	Hatchery Standards	√	√	√	√	X

1.1	Scheme Name	EUREP IFA January 2003	Assured Chicken Production Broiler Standard 2003/2004	Assured Chicken Production Free Range Standard 2003/2004	Freedom Foods January 2002	Soil Association July 2000
1.5.11	Standards for Catching, Transport and Slaughter	√	√	√	√	√
1.5.12	GMO Policy	X	X	X	X	√
2.1	<b>Health &amp; Safety/ Personnel Management</b> - Does the scheme define the following:					
2.1.1	Risk Assessment	√	X	X	X	X
2.1.2	Fire Fighting	√	√	√	X	X
2.1.3	First Aid	√	√	√	X	X
2.1.4	COSHH/Chemical Storage	√	√	√	X	X
2.1.5	Smoking Policy	√	√	√	X	X
2.1.6	Health and Safety Policy	√	X	X	X	X
2.1.7	Personnel welfare requirements	√	X	X	X	X
2.1.8	Training – food safety hygiene	√	√	√	X	X
2.1.9	Training – health and safety	√	√	√	X	X
2.1.10	Training – bird welfare and health	√	√	√	√	X
2.1.11	Training- general/ bird management practices	√	√	√	√	√
2.2	<b>Environmental Management</b> (incl. records required by IPPC) Does the scheme define the following:			May not be applicable as units less than 40,000 birds.	May not be applicable as units less than 40,000 birds.	May not be applicable as units less than 40,000 birds.
2.2.1	Inventory of raw materials	X	X	X	X	√
2.2.2	Inspection of buildings/ equipment	X	X	X	X	X
2.2.3	Waste minimization audit	√	X	X	X	X
2.2.4	Manure (Farm waste) management plan	√	√	√	X	√
2.2.5	Water use audit	X	X	X	X	X
2.2.6	Energy use audit	√	X	X	X	X
2.2.7	Emergency plans	√	√	√	√	X
2.2.8	Spillage procedures	√	X	X	X	X
2.2.9	Noise management plan	X	X	X	X	X
2.2.10	Odour management plan	X	X	X	X	X
2.2.11	Site drainage plan	X	X	X	X	X
2.2.12	Decommissioning plan	X	X	X	X	X
2.2.13	Carcase management	√	√	√	√	X
2.3	<b>Conservation Management</b> Does the scheme define the following:					
2.3.1	Conservation Plan (Biodiversity Action Plan)	√	X	√	X	√
2.3.2	Nitrate levels in ground water	√	X	√	X	X
2.4	<b>Welfare Management</b> (some also food safety) Does the scheme define the following:					
2.4.1	Welfare Policy required	√	√	√	√	X
2.4.2	Litter management	√	√	√	√	√
2.4.3	Air quality	√	√	X	√	√
2.4.4	Heat/cold stress procedure	√	√	X	√	X
2.4.5	Stocking density kg/m <sup>2</sup>	Standard 34 Barn reared 25 Free range 27.5	34 – max 38	Compliance with EU Directive	Max. 30	Fixed housing – 21 Mobile housing 30

1.1	Scheme Name	EUREP IFA January 2003	Assured Chicken Production Broiler Standard 2003/2004	Assured Chicken Production Free Range Standard 2003/2004	Freedom Foods January 2002	Soil Association July 2000
2.4.6	Leg problems-culling records	√	√	√	√	X
2.4.7	Bristol Gait scoring	√	X	X	√	X
2.4.8	Catching procedures	√	√	√	√	X
2.4.9	Culling methods/training	√	√	√	√	X
2.4.10	Lighting programme	√	√	√	√	√
2.4.11	Breast blisters, hock burn	√ hockburn)	√ (hock burn)	√	√	√ (hockburn)
2.4.12	Pododermatitis	√	X	√	√	X
2.4.13	Flock performance data monitored	√	√	√	√	√
2.4.14	Water system standards	√	√	√	√	√
2.4.15	Water consumption monitored	√	√	√	√	X
2.4.16	Medicines control policy (including POM) and book maintained	√	√	√	√	√
2.4.17	Vaccination procedure/ programme	√	√	√	√	√
2.4.18	Disease management/ Veterinary health plan	√	√	√	√	√
2.4.19	Feed standards	√	√	√	√	√
2.4.20	Numbered feed bins	√	√	√	X	X
2.4.21	Feed traceability records	√	√	√	√	√
2.4.22	Feed control programme incl. organic acid addition.	√	√	√	x	X
2.4.23	Provision for emergency drinking water	√	√	√	X	X
2.4.24	Back up power supply available	√	√	√	√	X
2.4.25	Services of veterinarian retained	√	√	√	√	√
2.4.26	Flock inspection requirements	2 x daily	2 x daily	2 x daily	3 x daily	3 x daily
2.4.27	Chick welfare	√	√	√	√	X
2.5	<b>Food Safety Management –</b> (some also welfare management controls) Does the scheme define the following:					
2.5.1	HACCP Study or site food safety plan	X	X	X	X	X
2.5.2	Pathogen/Salmonella control policy	√	√	√	√	X
2.5.3	Parent stock Salmonella vaccination	X	√	X	X	X
2.5.4	Salmonella litter testing	√	√	√	X	X
2.5.5	Campylobacter testing	X	X	X	X	X
2.5.6	Bird/Flock/Egg Traceability Procedure/Records	√	√	√	√	√
2.5.7	Cleaning/ disinfection policy	√	√	√	√	√
2.5.8	Post cleaning swabs	√	√	√	√	X
2.5.9	Defra approved disinfectants and detergents	X	√	√	X	Approved list
2.5.10	Water testing policy	√	√	√	X	X
2.5.11	Pest control programme	√	√	√	√	√
2.5.12	Vegetation management	X	√	√	√	X
2.5.13	Biosecurity programme	√	√	√	√	X
2.5.14	Visitors record	√	√	√	X	X
2.5.15	Handwashing facilities	√	√	√	X	X
2.5.16	Site designated clothing	√	√	√	X	X

1.1	Scheme Name	EUREP IFA January 2003	Assured Chicken Production Broiler Standard 2003/2004	Assured Chicken Production Free Range Standard 2003/2004	Freedom Foods January 2002	Soil Association July 2000
2.5.17	Vehicle hygiene	√	√	√	X	X
2.5.18	Approved drugs list	√	√	√	X	Approved list
2.5.19	Antibiotic residue testing	√	X	X	X	X
2.5.20	Requirement to have a period free of livestock	√	√	√	X	√
<b>2.6</b>	<b>External Audit, inspection or verification</b>					
2.6.1	Is the scheme subject to external inspection by the Purchaser?	√	√	√	√	√
2.6.2	Is the scheme subject to external inspection by an independent appointed body?	√	√	√	√	√
2.6.3	Certification bodies accredited to EN45011	√	√	√	√	√

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Published Papers

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2007

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## PEER REVIEWED PUBLICATIONS

1. Manning L., and Baines R.N., Effective management of food safety and quality. British Food Journal Vol. 106. No. 8, 2004 pp 598-606 Emerald Group Publishing.
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